



National Aeronautics and Space Administration



# UAS Integration into the NAS: iHITL: DAA Display Evaluation Preliminary Results

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# Overview



- Goals:
  1. Leverage the lessons learned from PT4 to continue the evaluation of candidate Sense and Avoid (SAA) with respect to pilot performance of the self-separation function
    - What are the individual contributions of the various PT4 advanced display features to pilots' response times and ability to maintain well clear?
  2. Introduce non-cooperative intruders to examine effect of different sensor ranges on pilots ability to maintain well clear
- Rationale
  - PT4 compared a 'Basic' display configuration to a suite of 'Advanced' features
    - iHitL design will allow us to measure any differences between specific display features and determine the implications of their presence or absence in the GCS
  - Non-cooperative traffic are a major consideration in the development of SAA systems
    - The presence of non-cooperative aircraft provides a more realistic environment
    - Limited surveillance range and field of regard may have significant impact on pilot performance and behavior



# Experimental Design



- One-Way Repeated Measures Factorial: Display Information Level (4 Level; Within Subjects)
  - D1: Advanced Display with Information Only
  - D2: Advanced Display with Information + Vector Planner
  - D3: Advanced Display with Information + Auto Resolutions
  - D4: Advanced Display with Information + Vector Planner + Auto Resolutions
    - Roughly same as 'Advanced' suite in PT4
- Embedded Variable
  - Track Type (manipulated within each scenario; not counterbalanced)
    1. Cooperative Traffic (ADS-B-equipped)
      - Range = 80nm & +/- 5000ft
    2. Non-Cooperative Traffic
      - Range = 6nm
      - Azimuth = +/- 110deg (from nose)
      - Elevation = +/- 20deg (from horizontal)

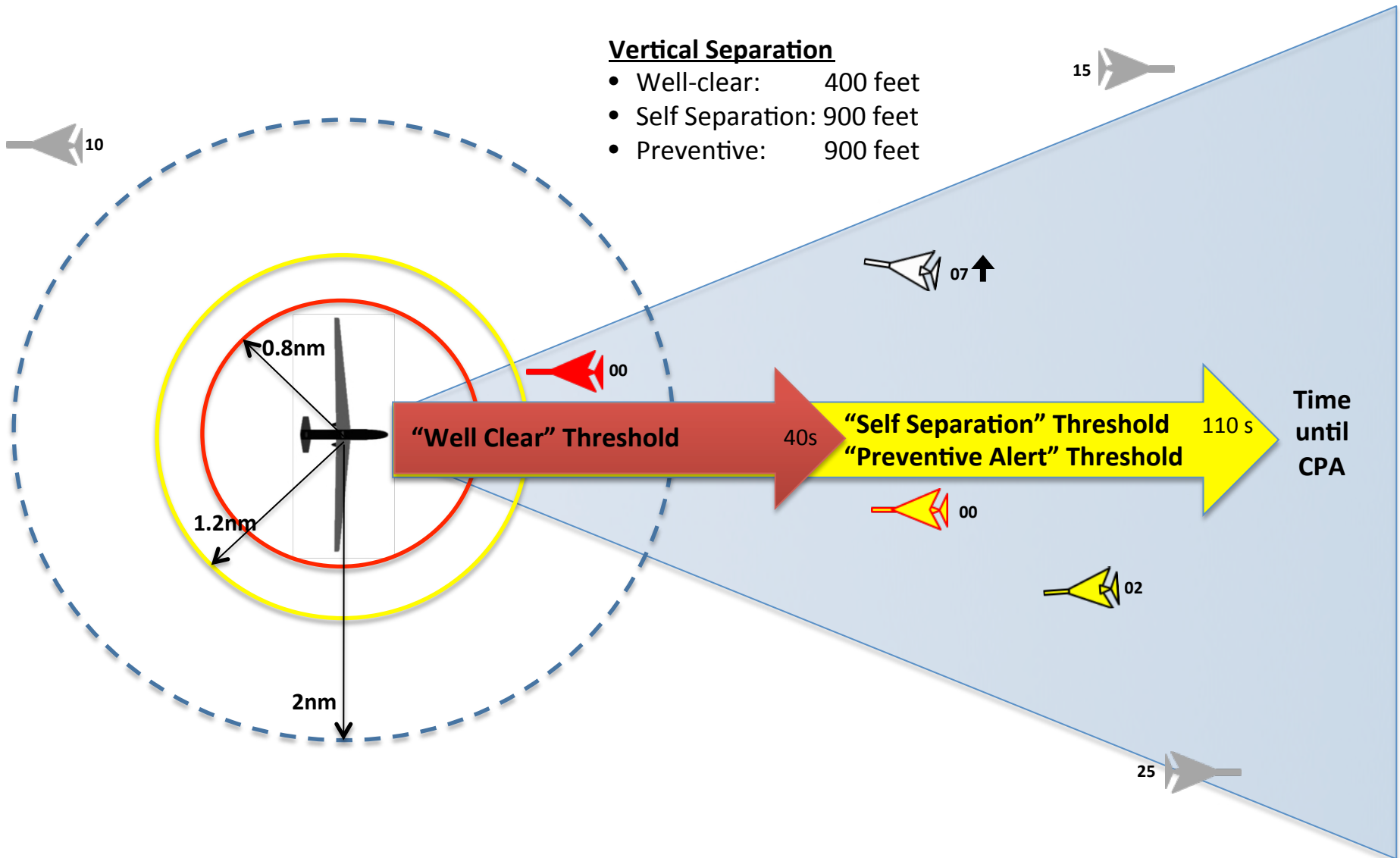


# Alerting Criteria



## Vertical Separation

- Well-clear: 400 feet
- Self Separation: 900 feet
- Preventive: 900 feet



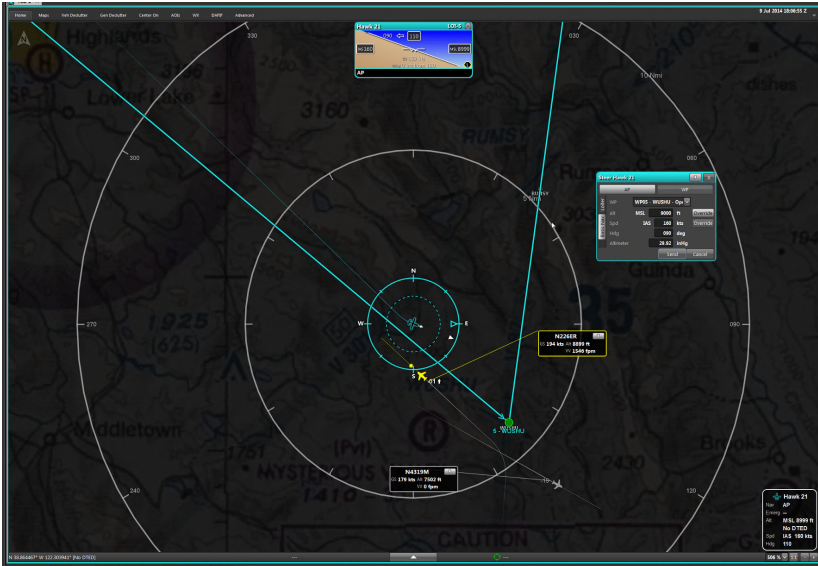




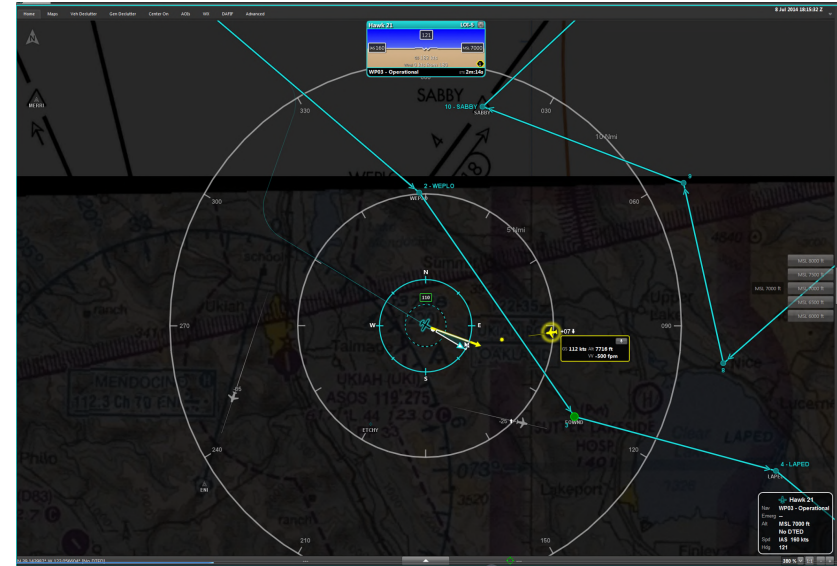
# Display Conditions



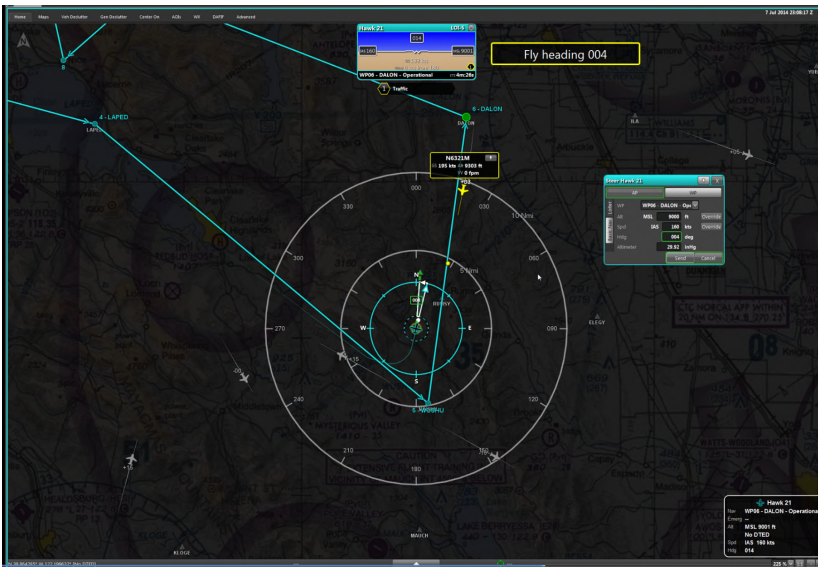
D1



D2



D3

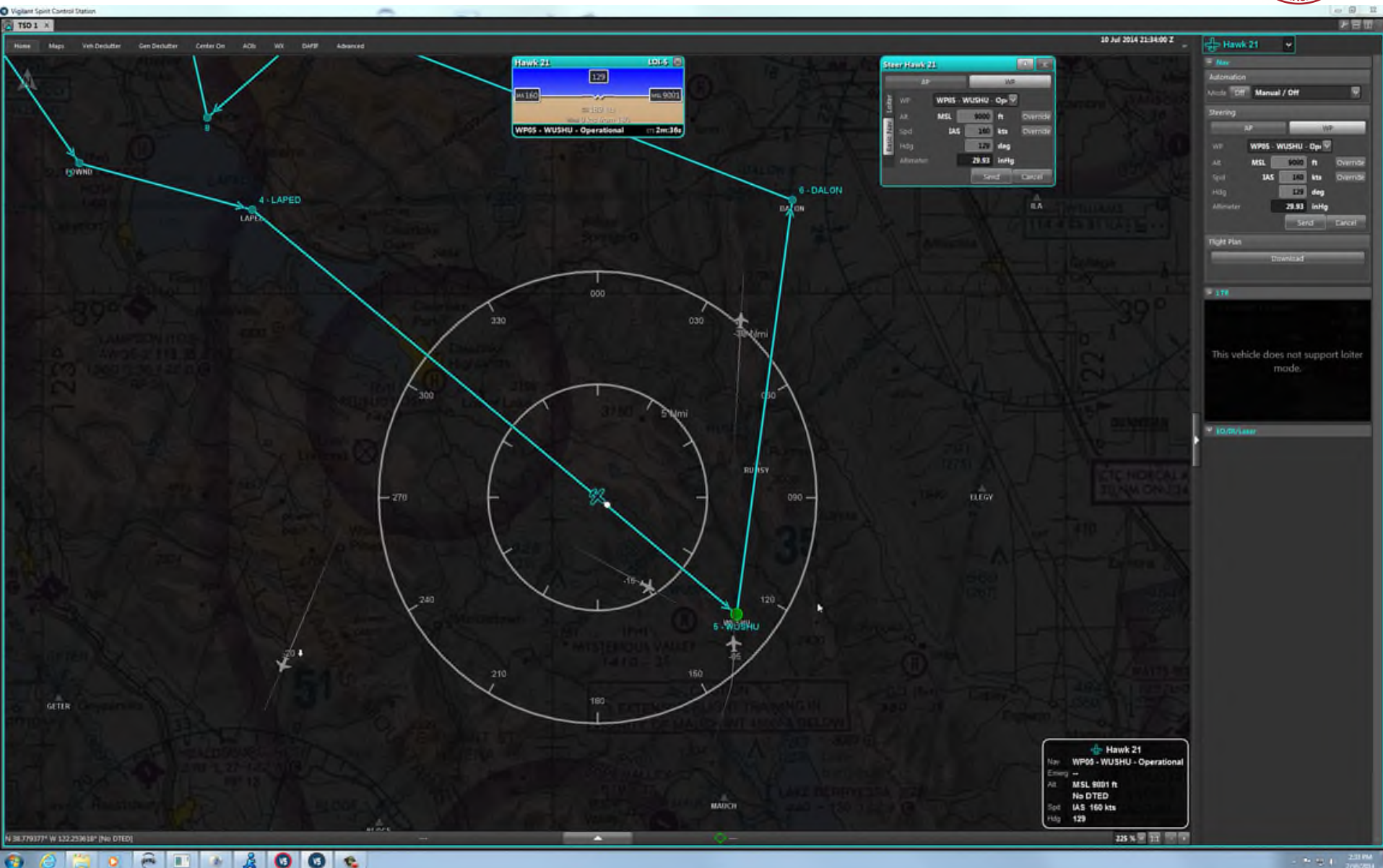


D4

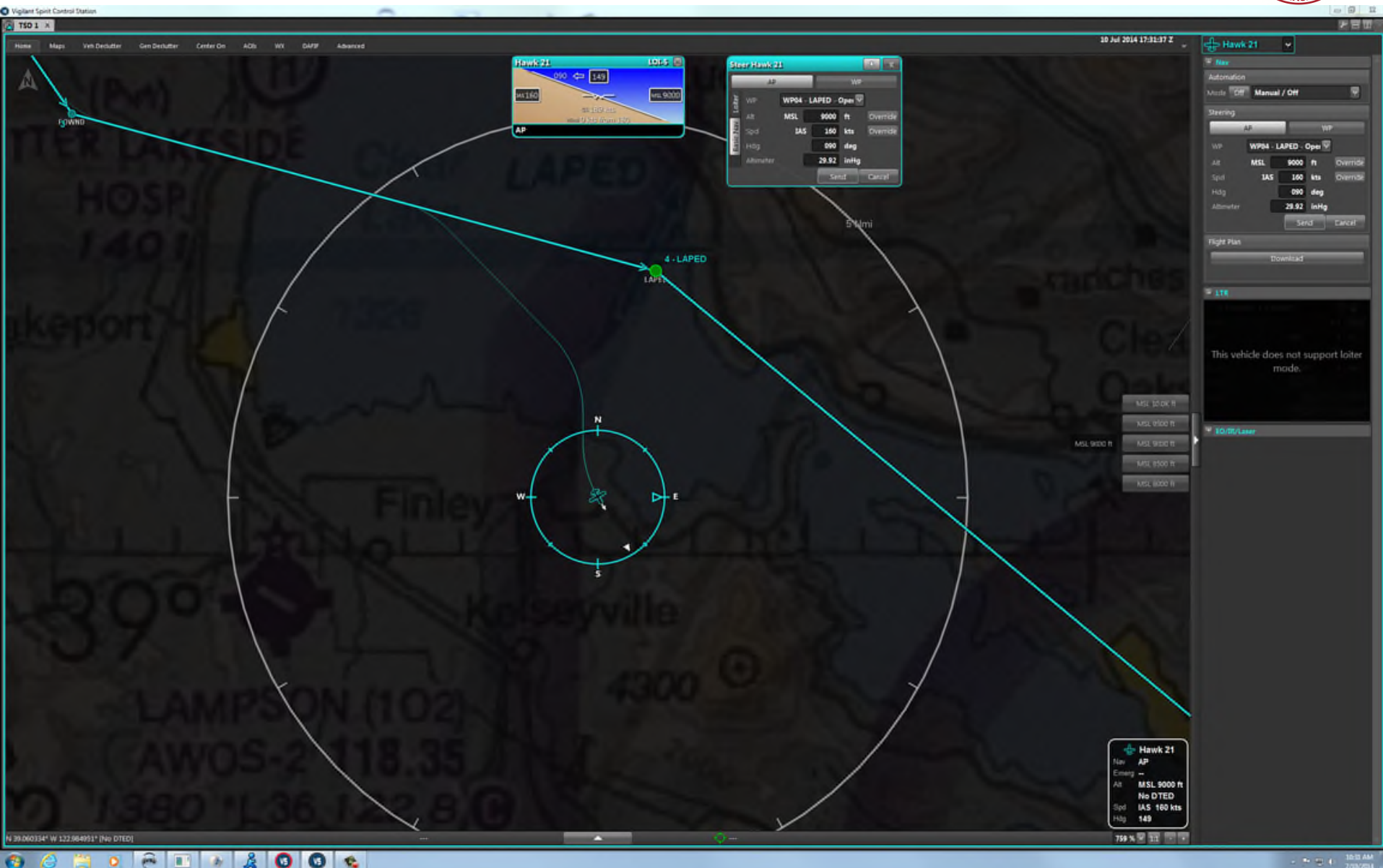




# D1 Encounter

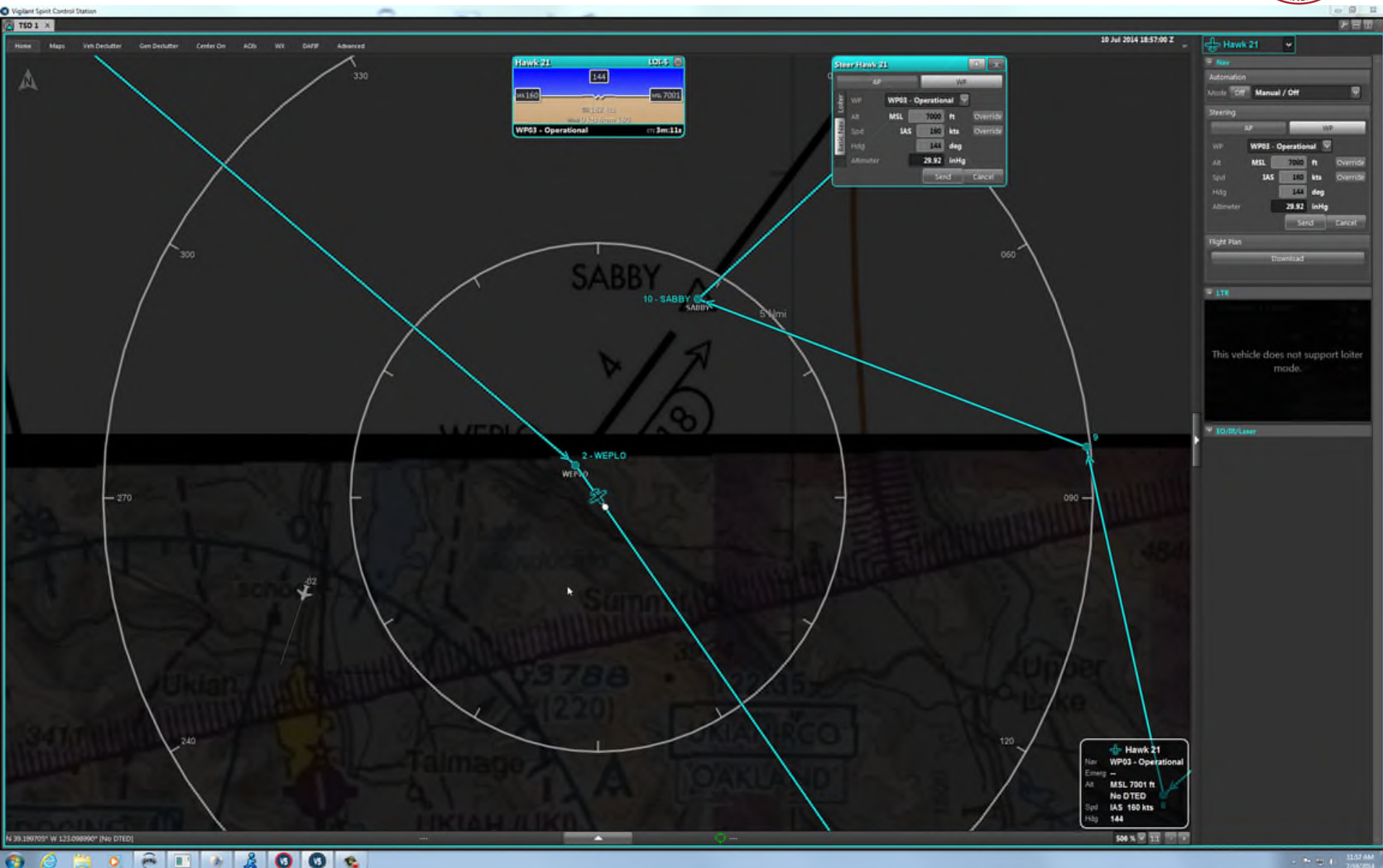








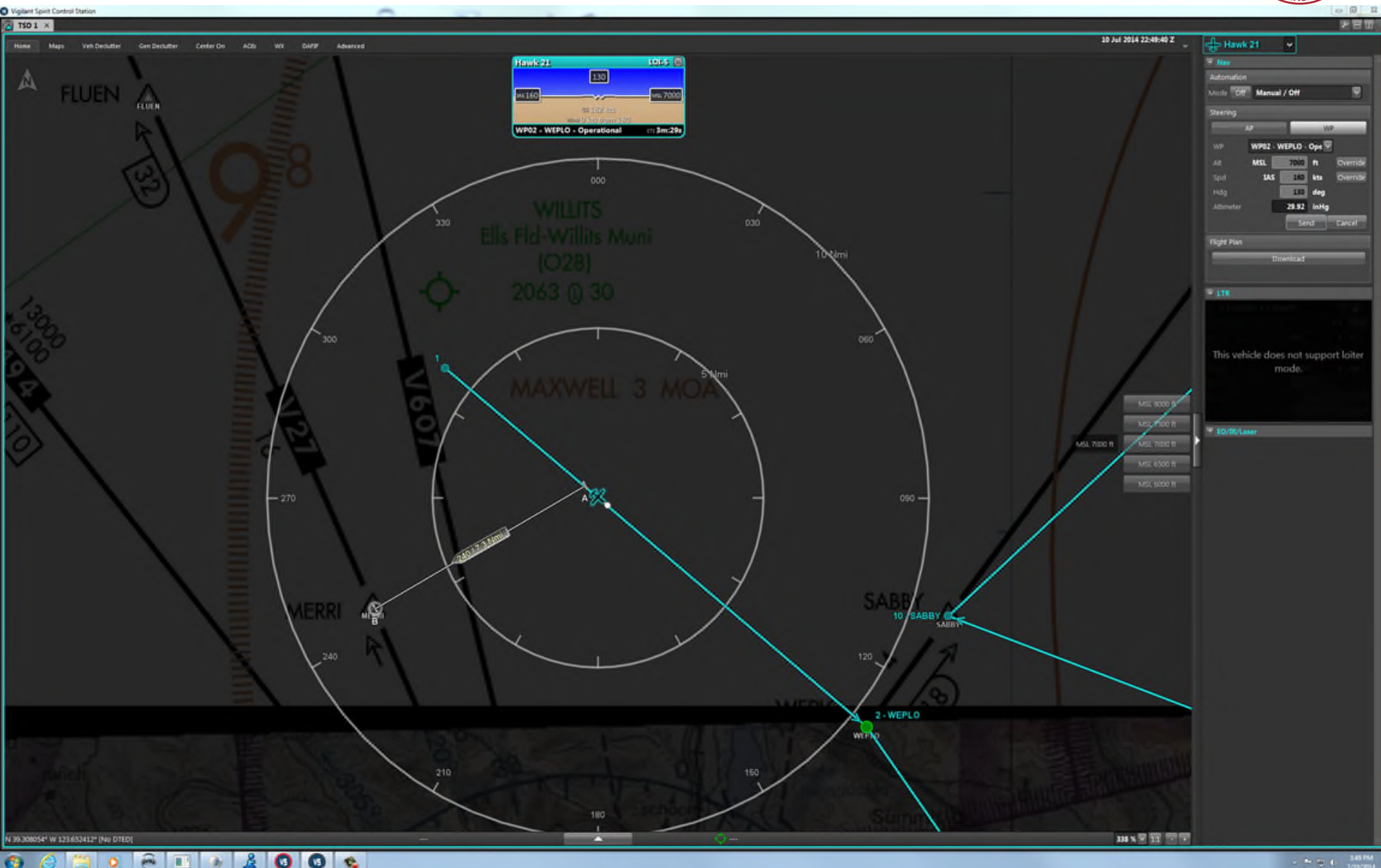
# D3 Encounter







# D4 Encounter





# Participants



- Participants:
  - 4 MQ-1 Predator/MQ-9 Reaper Pilots (avg. 46 years old)
    - All received Undergraduate Pilot Training
  - 5 RQ-4 Global Hawk Pilots (avg. 33 years old)
    - 3 received Undergraduate Pilot Training
    - 1 received RQ-4 Basic Training (AF Specialty Code 18X)
    - 1 received cross training
  - All 9 pilots had military UAS experience
    - Military Combat & Non-Combat Experience = avg. 1182 hours
    - Civilian Airspace = avg. 153 hours
      - 5 pilots had less than 50 hours of experience flying in civilian airspace
  - 1 retired Air Traffic Controller with experience in Oakland Center airspace (confederate)



# Procedure



- UAS Scenario (38min)
  - UAS: Predator B
  - Airspace: ZOA 40/41
    - Class A & E with mixed IFR/VFR traffic
    - Manned traffic modeled using real traffic data
- Primary Tasks:
  1. Fly HAWK21 along pre-filed path (Fire Line)
    - Only responsible for navigating the aircraft
    - Requires interaction with the GCS and coordination ATC
  2. Comply with ATC clearances and traffic display alerts to maintain safety of flight
- Secondary tasks:
  - ‘Chat’ directed
    - “Mission” Radio Frequency changes
    - Radial and Distance check
    - Nominal information requests (e.g., fuel level remaining)
  - System Alerts
    - Generator Failure (checklist)
    - Tanker Header Overpressure (checklist)
    - Annunciator checks

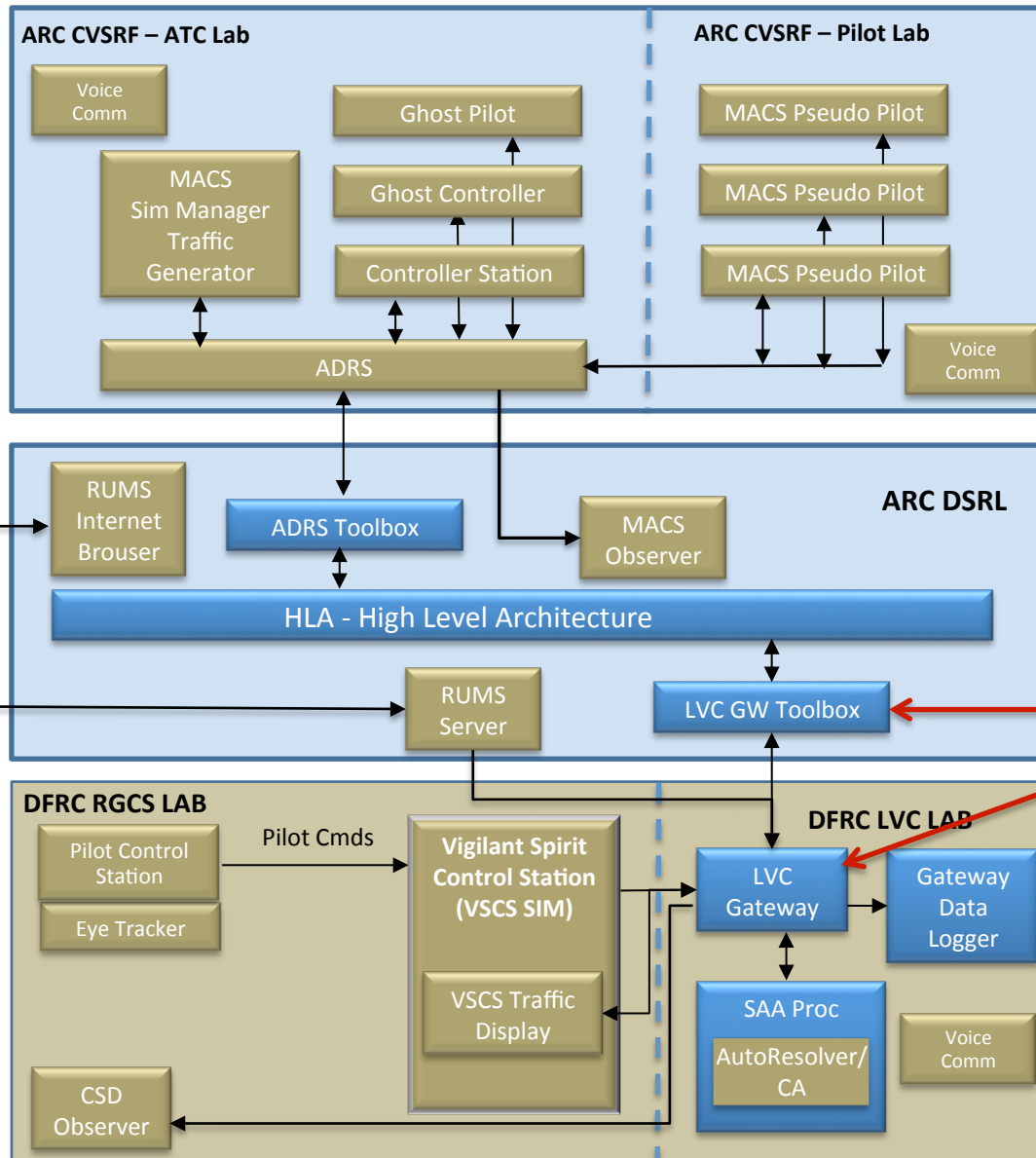






# Research Ground Control Station





## DIS Voice Tunneler

## IT&E Components

## LVC Participants & Displays



# Initial Research Question

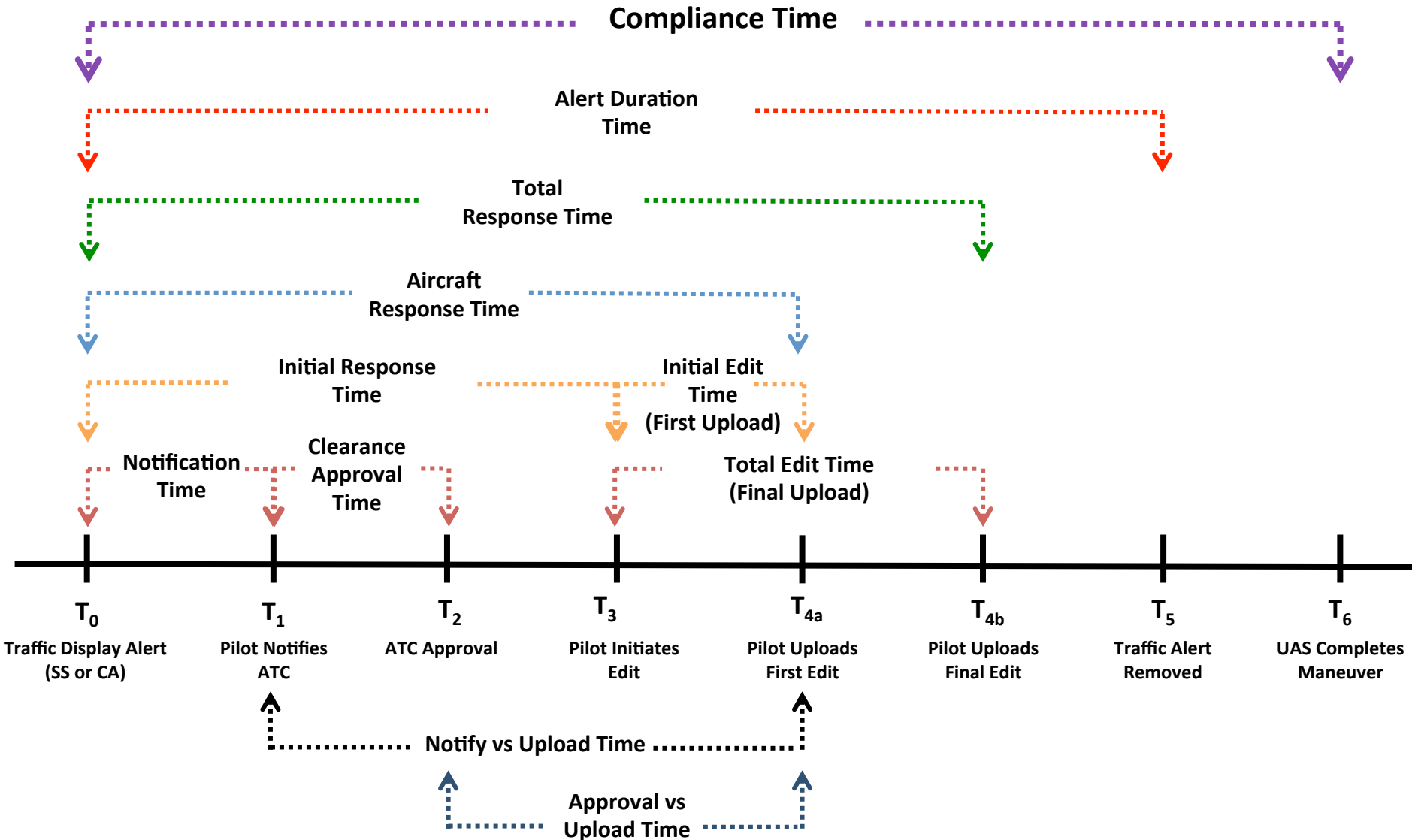


- What was the effect of the DAA guidance tools on pilots' performance in response to self separation alerts?
  - Same measured response metrics as those captured in PT4
- Measured Response data were analyzed utilizing 5 separate One-Way Analyses of Variance (ANOVAs)
  - I. Independent Variable: Display
    - 1) D1: Advanced Display with Information Only
    - 2) D2: Advanced Display with Information + Vector Planner
    - 3) D3: Advanced Display with Information + Auto Resolutions
    - 4) D4: Advanced Display with Information + Vector Planner + Auto Resolutions
  - II. Analyses for: Alert Type and Intruder Type
    - 1) All self separation (SS) alerts
    - 2) Predictive SS alerts (yellow with red outline; collapsed across Intruder Type)
    - 3) Non-Predictive SS alerts (yellow; collapsed across Intruder Type)
    - 4) Cooperative SS alerts (collapsed across Alert Type)
    - 5) Non-Cooperative SS alerts (collapsed across Alert Type)



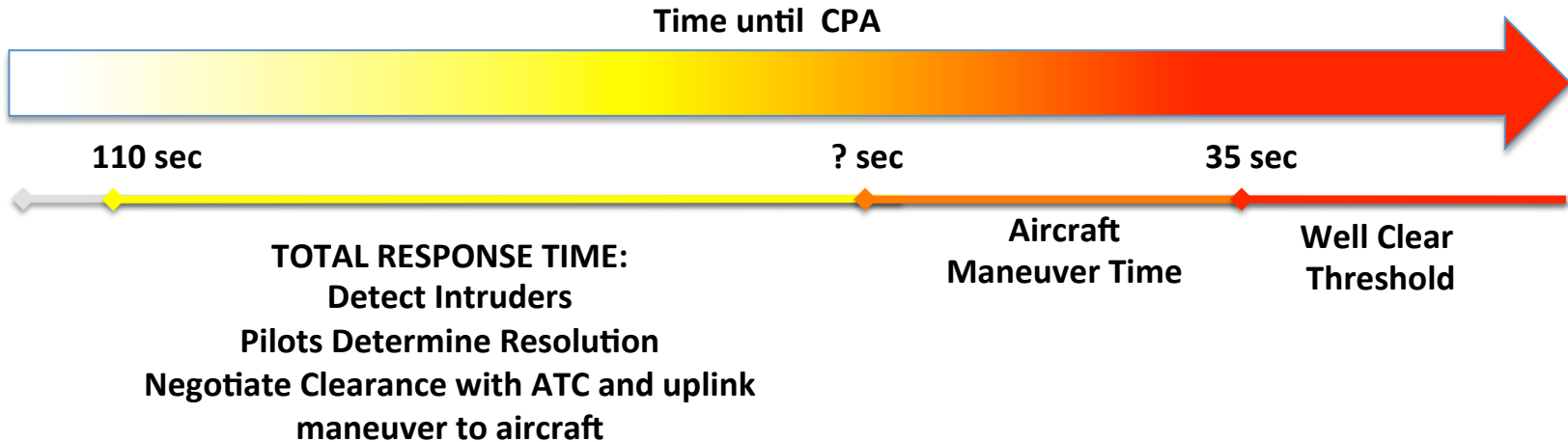


# Stages of Pilot DAA Task





# Self-Separation Timeline





# Encounter Statistics



- Total Number of Encounters:
  - Alert Type:
    - 134 Predictive SS Alerts
    - 115 Non-Predictive SS Alerts
  - Intruder Type:
    - 92 Cooperative
    - 157 Non-Cooperative
- Pilots responded to a total of 196 Self Separation Alerts
  - Alert Type:
    - 122 Predictive SS Alerts (91% of total)
    - 74 Non-Predictive SS Alerts (64% of total)
  - Intruder Type:
    - 61 Cooperative (66% of total)
    - 135 Non-Cooperative (86% of total)
  - Alert Type X Intruder Type:
    - 25 Cooperative/Predictive
    - 36 Cooperative/Non-Predictive
    - 97 Non-Cooperative/Predictive
    - 38 Non-Cooperative/Non-Predictive





# Data Slides Organization

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- Slides organized by metric
  - Analysis of Variance (ANOVA) results for All SS Alerts
    - Was there an effect of Display on the dependent variable?
  - ANOVA by Alert Type
  - ANOVA by Intruder Type
  - Means of the Alert/Intruder Type by Display
  - Means of Display by Alert/Intruder Type
  - Comparison of display means for PT4 and iHITL



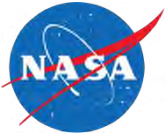
# iHITL Results



## Summary of Results

	PT4 Grand Mean	iHITL Grand Mean	All SS	Predictive	Non-Predictive	Cooperative	Non-Cooperative
Notification Time	29.07s	14.03s	X	X	X	X	X
Clearance Approval Time	5.08s	5.54s	X	X	X	X	X
ATC Notification vs Upload Time	3.51s	0.18s	p = .075	X	p < .05	p = .-55	X
ATC Approval vs Upload Time	-1.52s	-6.46s	p = .092	X	p < .05	p = .070	X
Initial Response Time	19.32s	8.52s	X	X	X	X	X
Initial Edit Time	11.77s	6.29s	p < .01	p < .05	p < .05	p < .01	p = .056
Total Edit Time	17.65s	9.83s	X	p < .05	X	X	p = .064
Aircraft Response Time	32.19s	14.54s	p = .069	p = .059	p < .05	p < .01	X
Total Response Time	37.87s	18.08s	X	p = .056	X	X	X
Alert Duration Time	48.61s	33.58s	X	X	X	X	X
Compliance Time	71.43s	37.53s	p < .05	p < .05	X	X	X

Only 6 significant differences between display conditions



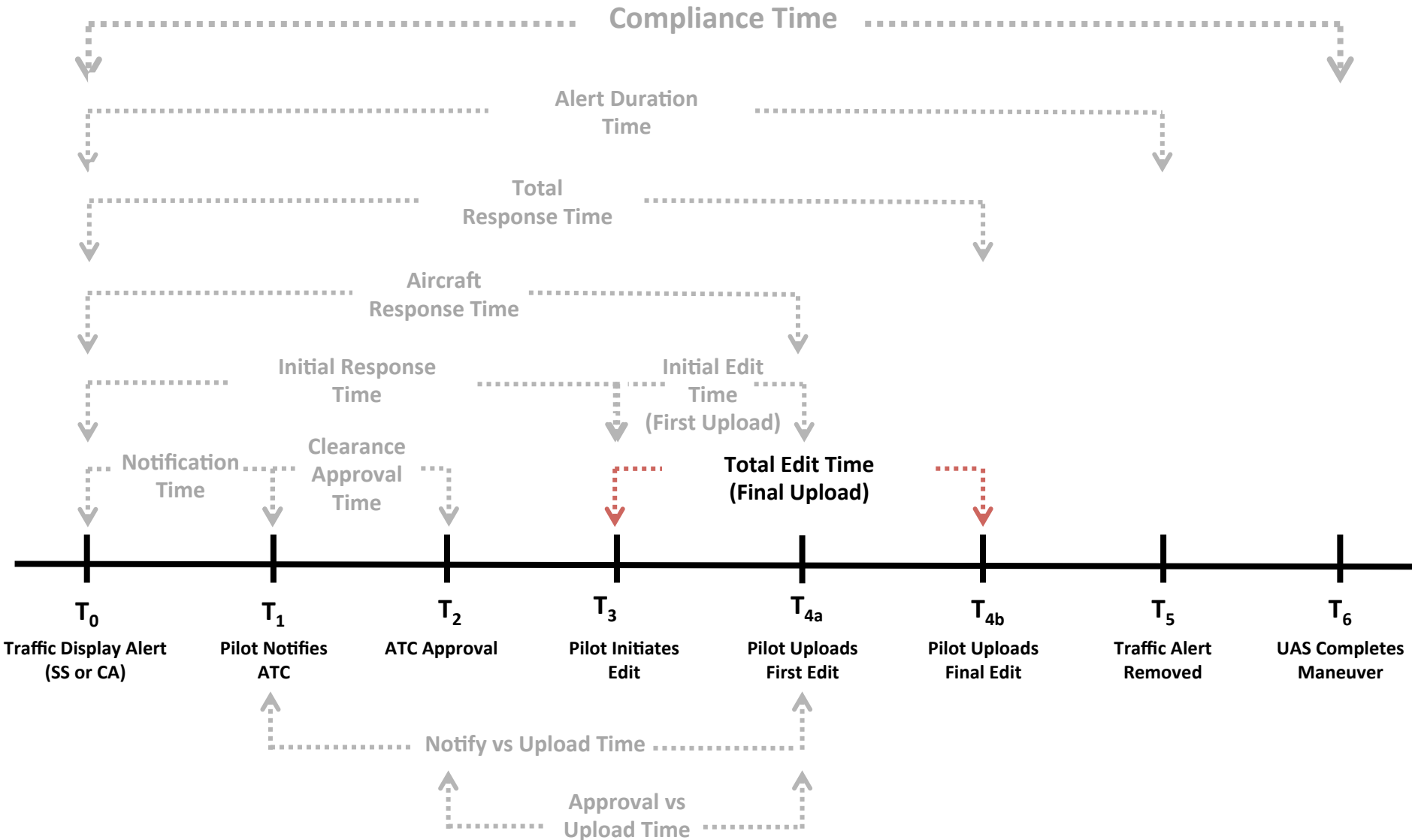
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**Some Results:**  
Total Edit Time  
Total Response Time



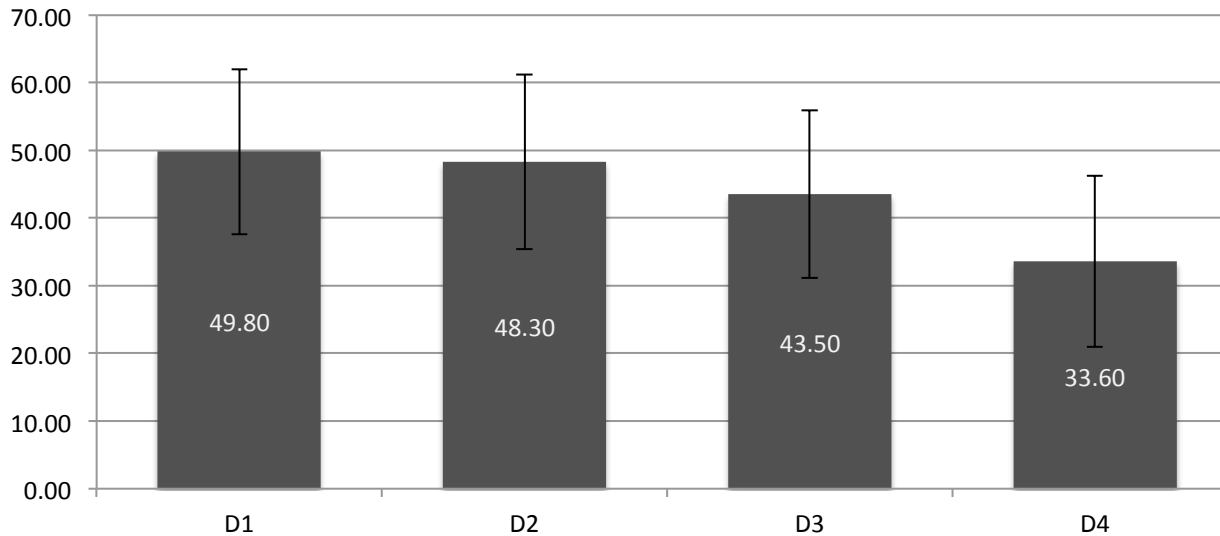


# Stages of Pilot DAA Task





# Total Edit Time

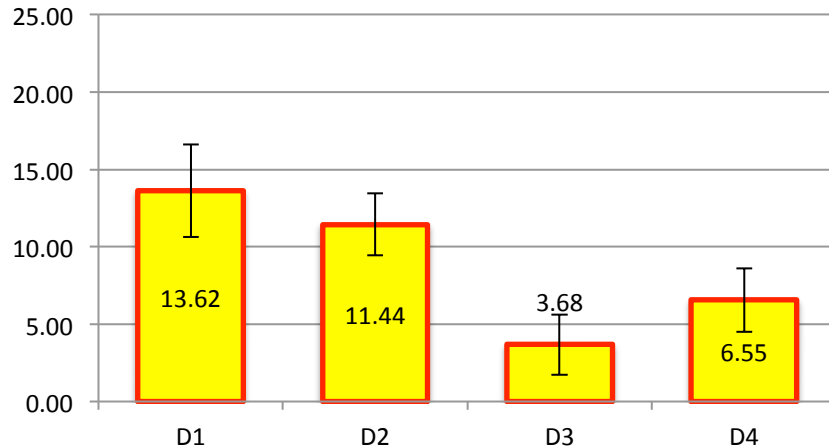


- There was a not significant effect of Display on Total Edit Time for all SS alerts,  $p > .05$
- Pilots took an average of **9.83 seconds** to complete their final edit in response to SS alerts



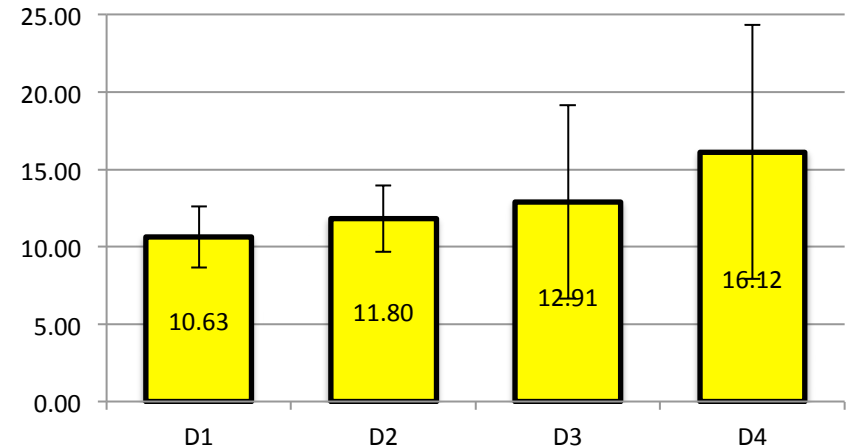
# Total Edit Time

## Predictive SS Alerts



- There was a significant effect of Display on Total Edit Time for Predictive alerts,  $p < .05$ 
  - D3 was significantly faster than D2, but no different than the other two displays
- Pilots took an average of **8.83 seconds** to complete their final edit in response to Predictive SS alerts

## Non-Predictive SS Alerts

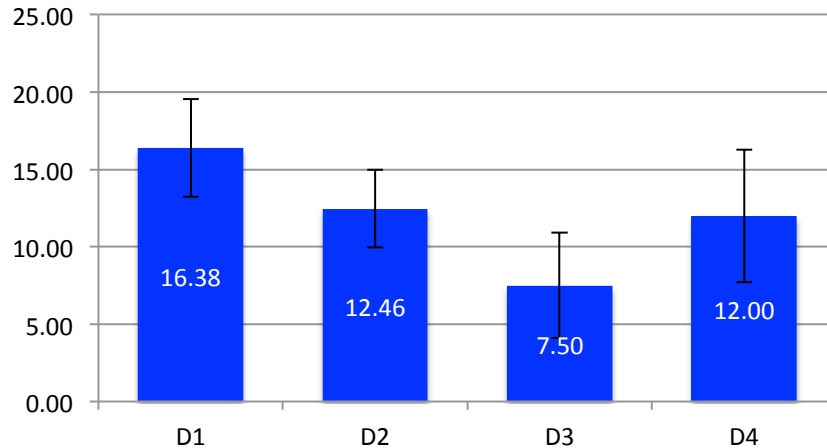


- There was no significant main effect of Display on Total Edit Time for Non-Predictive alerts,  $p > .05$
- Pilots took an average of **12.862 seconds** to complete their final edit in response to Non-Predictive SS alerts



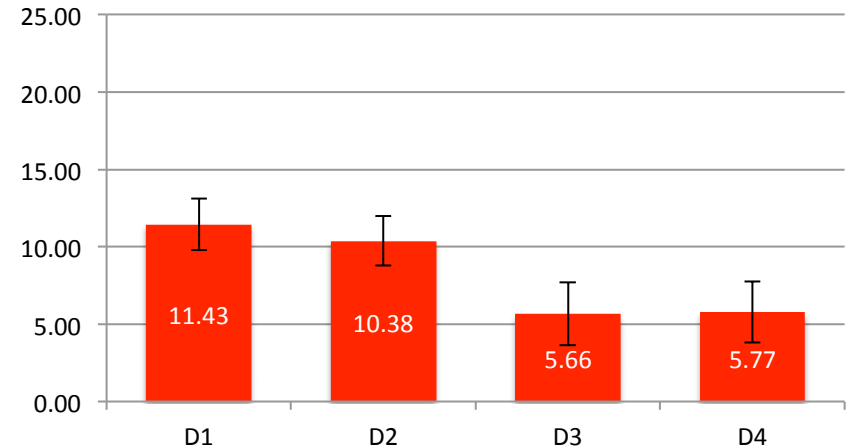
# Total Edit Time

## Cooperative SS Alerts



- There was no significant effect of Display on Total Edit Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **12.08 seconds** to complete their final edit in response to Cooperative SS alerts

## Non-Cooperative SS Alerts

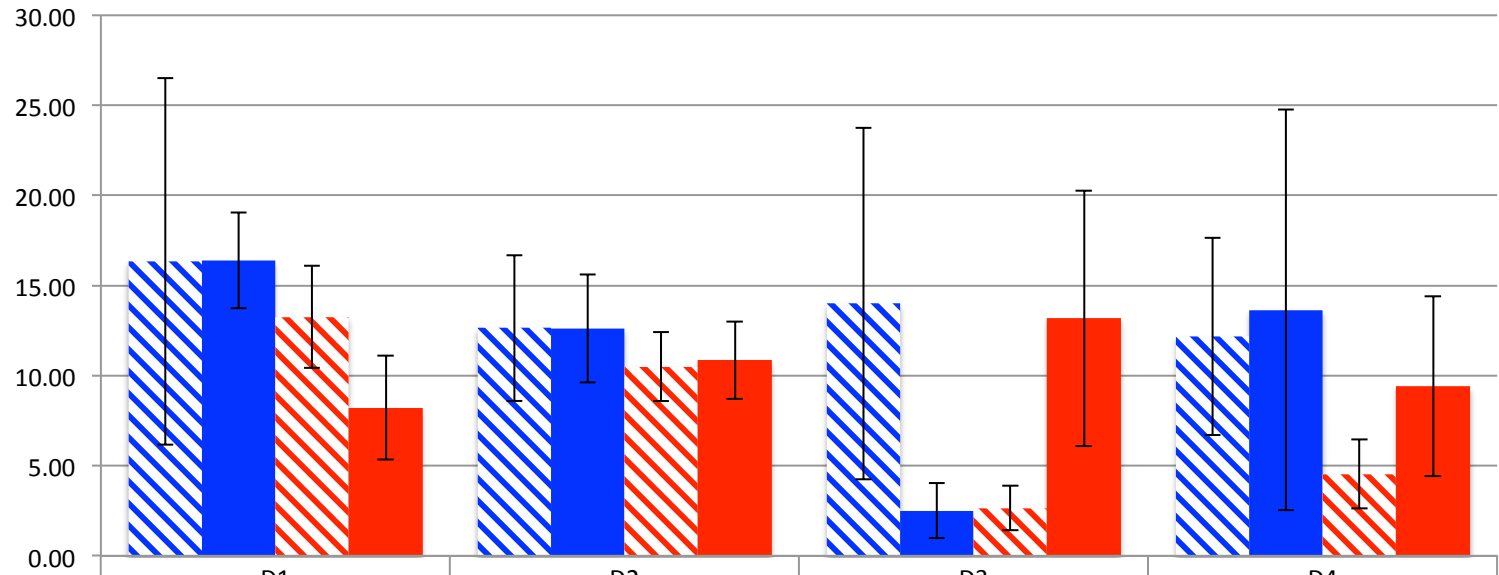


- There was a near significant effect of Display on Total Edit Time for Non-Cooperative SS alerts,  $p = .064$
- Pilots took an average of **8.31 seconds** to complete their final edit in response to Non-Cooperative alerts

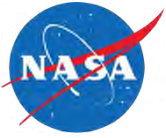




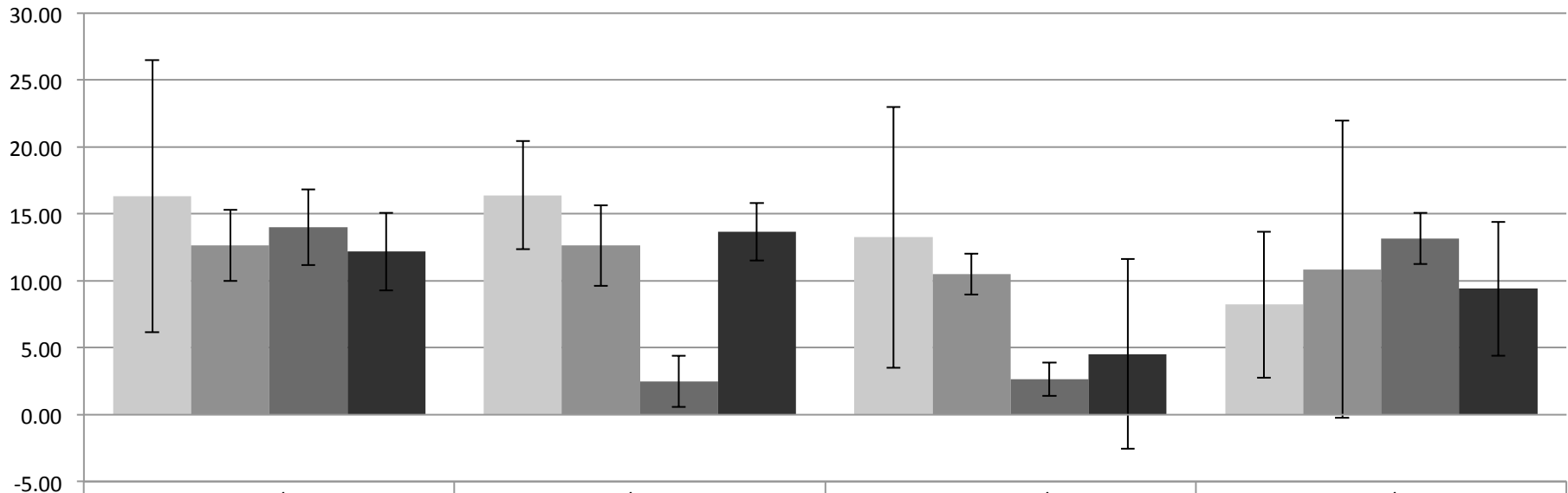
# Total Edit Time



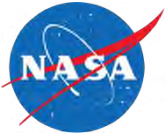
Cooperative/Predictive	D1	16.33	D2	12.64	D3	14.00	D4	12.17
Cooperative/Non-Predictive	D1	16.40	D2	12.63	D3	2.50	D4	13.64
Non-Cooperative/Predictive	D1	13.26	D2	10.50	D3	2.64	D4	4.54
Non-Cooperative/Non-Predictive	D1	8.21	D2	10.86	D3	13.17	D4	9.40



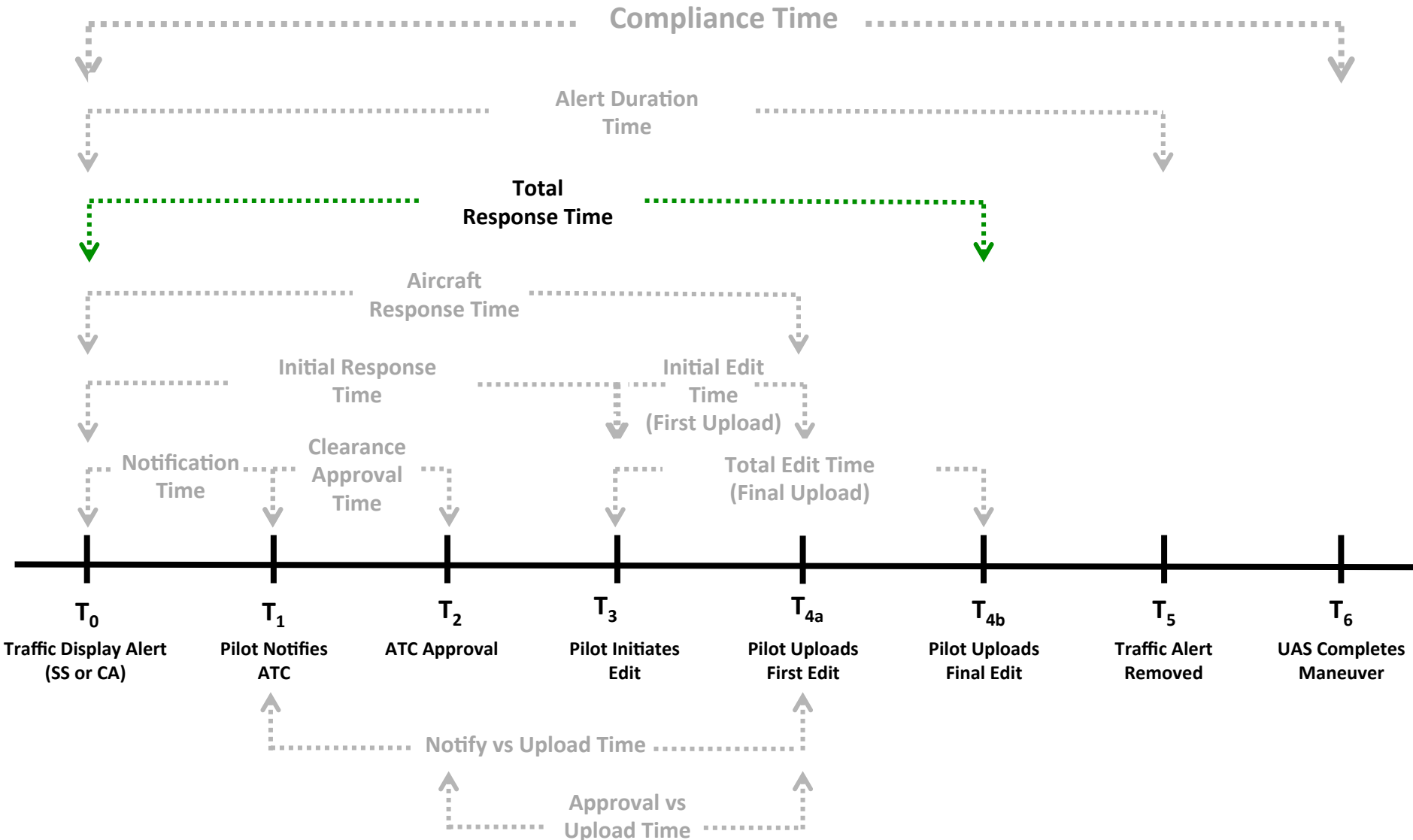
# Total Edit Time



	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
■ D1	16.33	16.40	13.26	8.21
■ D2	12.64	12.63	10.50	10.86
■ D3	14.00	2.50	2.64	13.17
■ D4	12.17	13.64	4.54	9.40

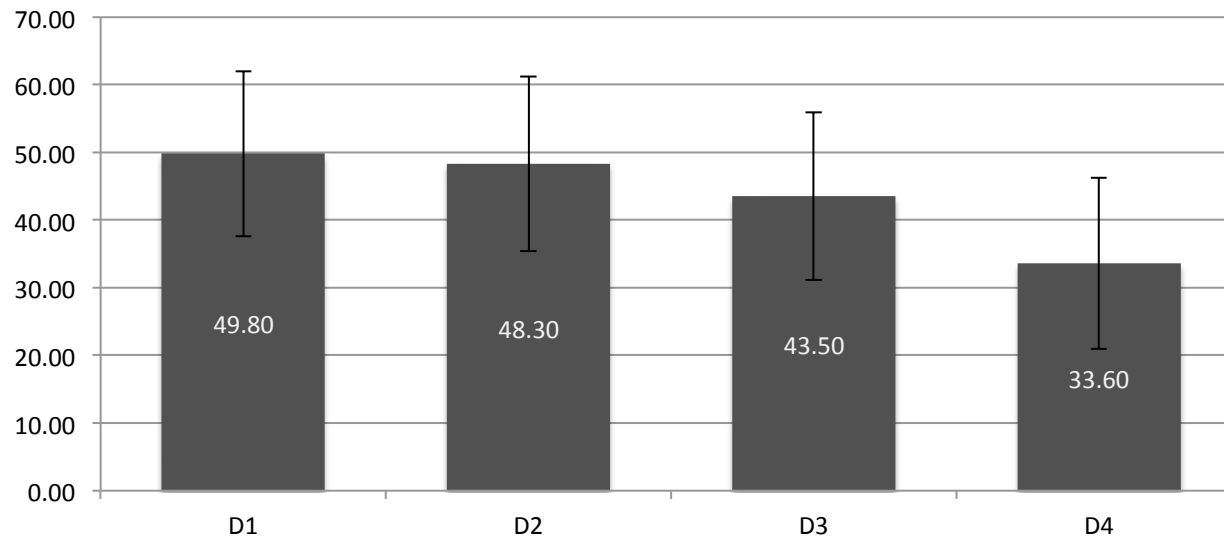


# Stages of Pilot DAA Task





# Total Response Time



- There was not a significant effect of Information on Total Response Time for all SS alerts,  $p > .05$
- Pilots took an average of **18.08 seconds** to complete their final edit in response to SS alerts (from first alert appearance)

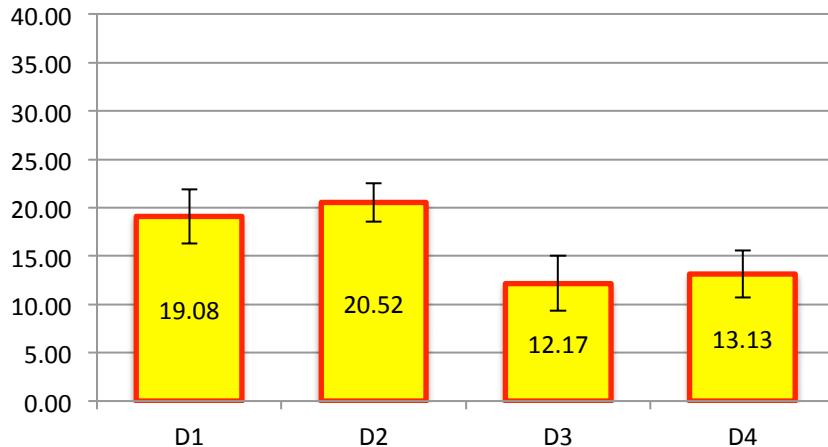




# Total Response Time

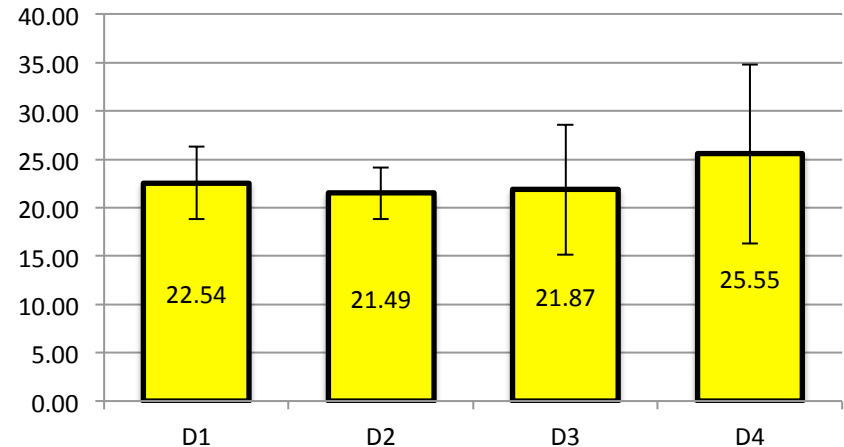


## Predictive SS Alerts



- There was a near significant effect of Display on Total Response Time for Predictive SS alerts,  $p = .056$
- Pilots took an average of **16.22 seconds** to complete their final edit in response to Predictive SS alerts (from first alert appearance)

## Non-Predictive SS Alerts



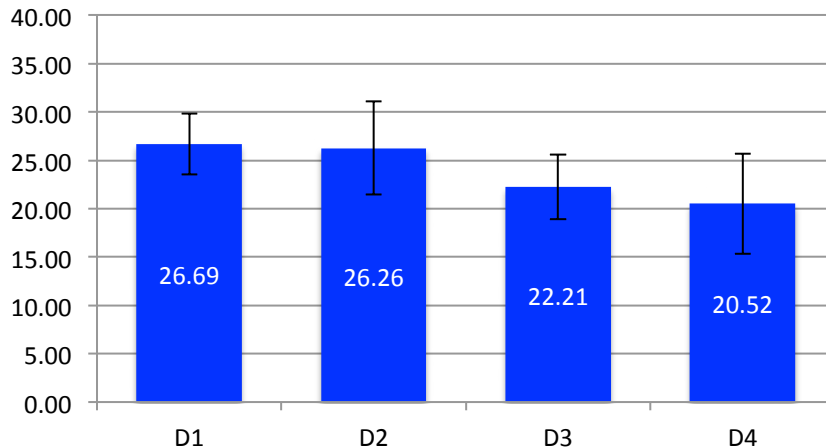
- There was no significant effect of Display on Total Response Time,  $p > .05$
- Pilots took an average of **22.86 seconds** to complete their final edit in response to Non-Predictive SS alerts (from first alert appearance)



# Total Response Time

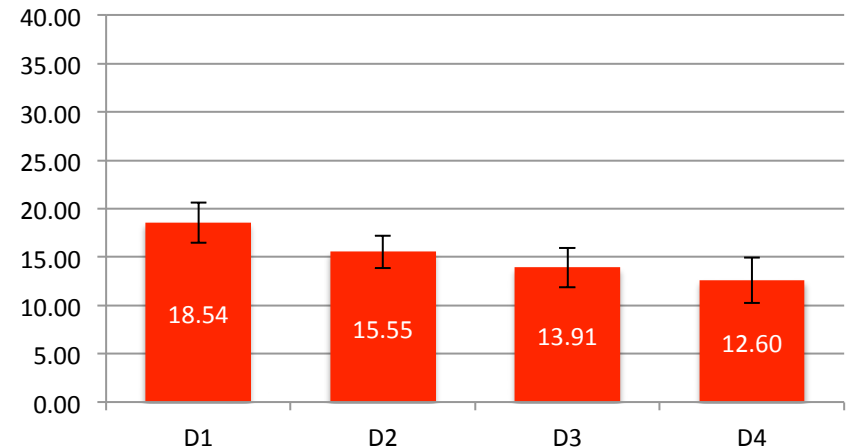


## Cooperative SS Alerts

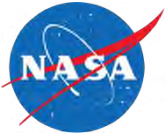


- There was no significant effect of Information on Aircraft Response Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **23.92 seconds** to complete their final edit in response to Cooperative SS alerts (from first alert appearance)

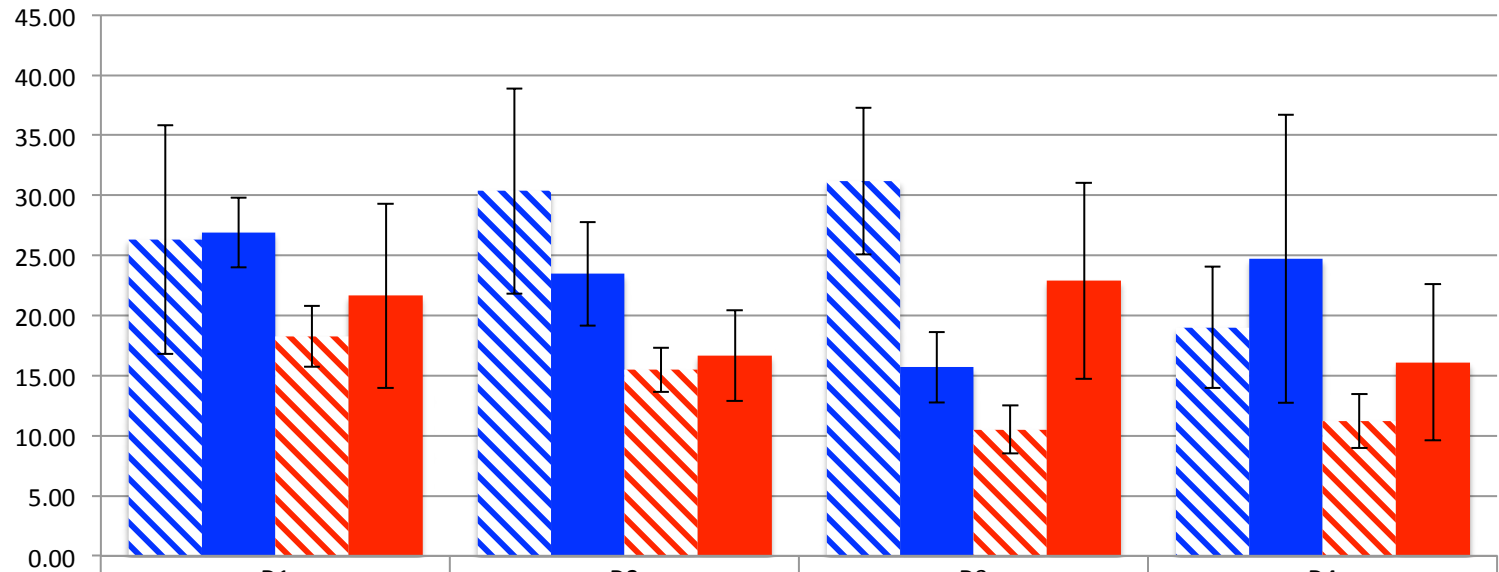
## Non-Cooperative SS Alerts



- There was no significant effect of Display on Aircraft Response Time for Non-Cooperative SS alerts,  $p > .05$
- Pilots took an average of **15.15 seconds** to complete their final edit in response to Non-Cooperative SS alerts (from first alert appearance)



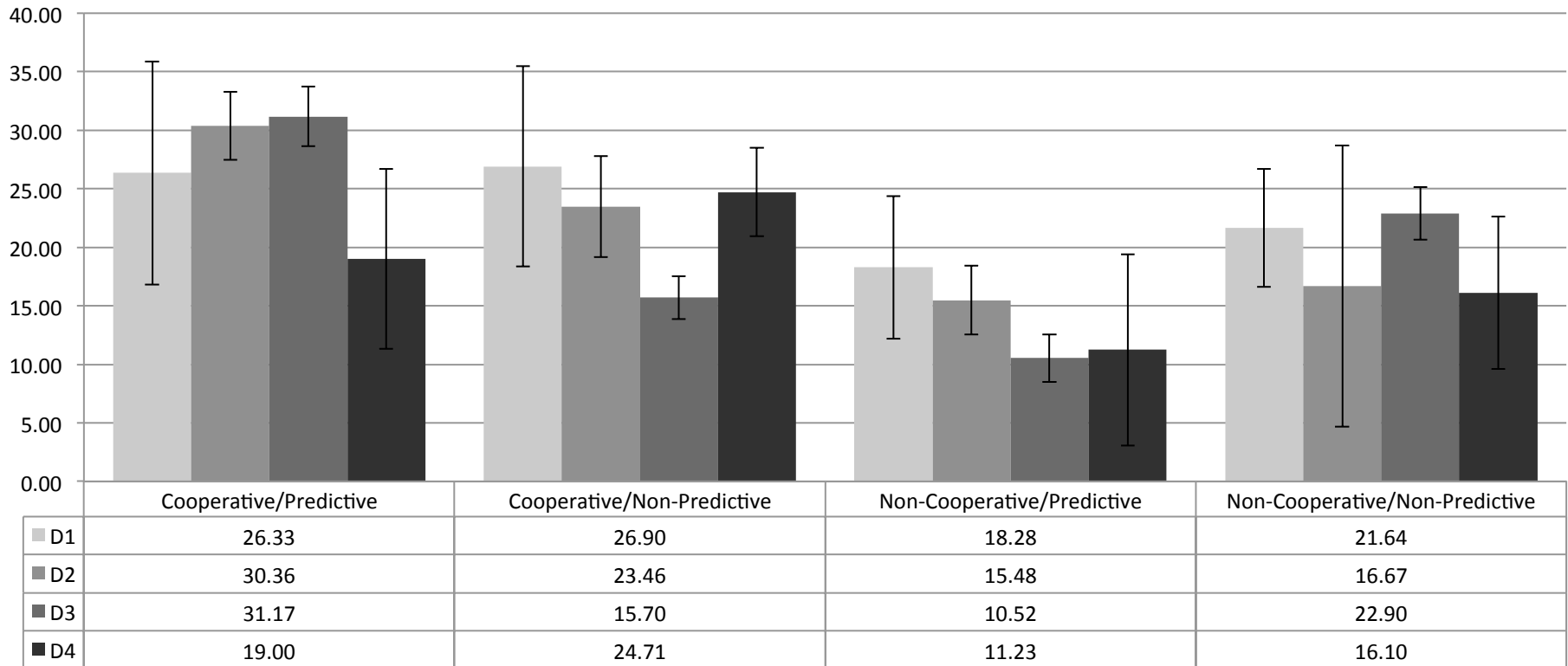
# Total Response Time

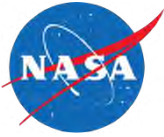


Cooperative/Predictive	D1	26.33	D2	30.36	D3	31.17	D4	19.00
Cooperative/Non-Predictive	D1	26.90	D2	23.46	D3	15.70	D4	24.71
Non-Cooperative/Predictive	D1	18.28	D2	15.48	D3	10.52	D4	11.23
Non-Cooperative/Non-Predictive	D1	21.64	D2	16.67	D3	22.90	D4	16.10



# Total Response Time





# iHITL Results Summary



- Few Meaningful Significant Results
  - Except for one, all for edit times where D3, and sometimes D4, are significantly faster
  - Does not translate to significant difference in total response time
    - No more than 8.5s difference between fastest and slowest times from Non-Cooperative/Predictive
- Some overall Trends:
  - Predictive alerts tended to have faster response times than Non-Predictive alerts
  - Non-Cooperative alerts tended to have faster response times than Cooperative alerts
  - Except for Edit Times, appears to be less variability across Intruder/Alert (especially Non-Cooperative/Predictive) type than Display type





# iHITL Results Summary



- Initial Response Time:
  - Non-Cooperative on average 5 seconds faster than Cooperative
  - Intruder/alert type appears more predictive of response time with low variability between D1 – D4
  - Non-Cooperative/Predictive fastest overall
- Initial Edit Time:
  - D3 consistently significantly fastest
  - D1 consistently significantly slowest
  - Lower variability for D3 and D2, higher variability for D1 and D4 across Intruder type
- Total Edit Time:
  - D3 significantly faster than D2 for Predictive SS alerts only (about 8 seconds faster)
  - Non-Cooperative on average 4 seconds faster than Cooperative
  - Least variability in D2 across Intruder/Alert Type
- Aircraft Response Time
  - D4 significantly faster than D1 and D2 (10-20 seconds)
  - Lowest and least variability in response times for Non-Cooperative/Predictive
  - Least variability in D4
- Total Response Time
  - No significant results
  - Predictive on average 5.5 seconds faster than Non-Predictive
  - Non-Cooperative on average 9 seconds faster than cooperative

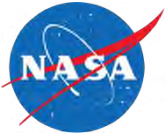


# iHITL and PT4 Results



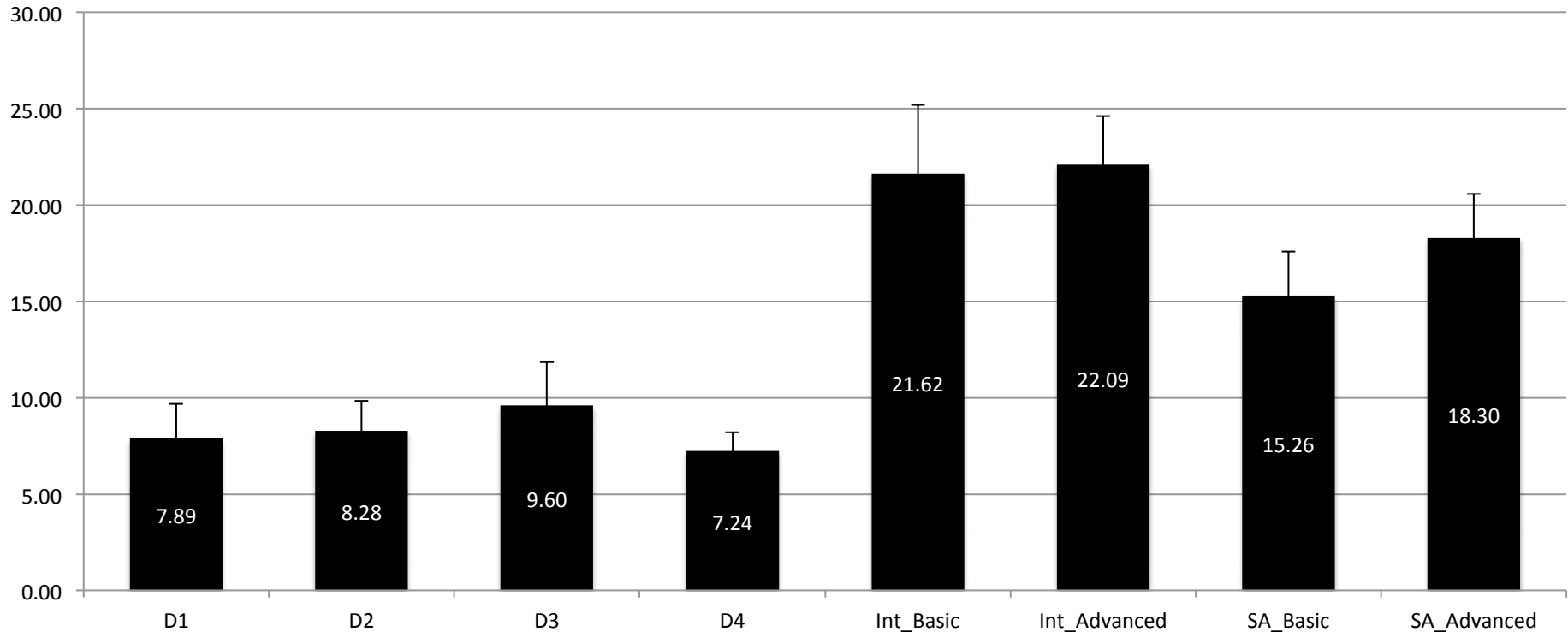
- iHITL Response Times faster than PT4 Response Times
- Closest comparisons:
  - PT4 Basic\_Integrated (Basic) vs. iHITL D1
    - D1 **added** information: predictive alert level, well clear ring, intruder CPA location
  - PT4 Advanced\_Integrated (Advanced) vs. iHITL D4
    - D4 **removed** information: vertical situation display, ownship CPA, time to CPA
- Initial Response Time, about 11 seconds faster overall (19.32s vs. 8.52s)
- Total Edit Time, about 8 seconds faster overall (17.65s vs. 9.82s)
- Total Response Time, about 8 seconds faster overall (37.87s vs. 18.08s)

Measure	PT4 Basic	iHITL D1	PT4 Advanced	iHITL D4
Initial Response Time	22	8	22	7
Total Edit Time	23	13	10	9
Total Response Time	45	21	32	16



# Initial Response Time

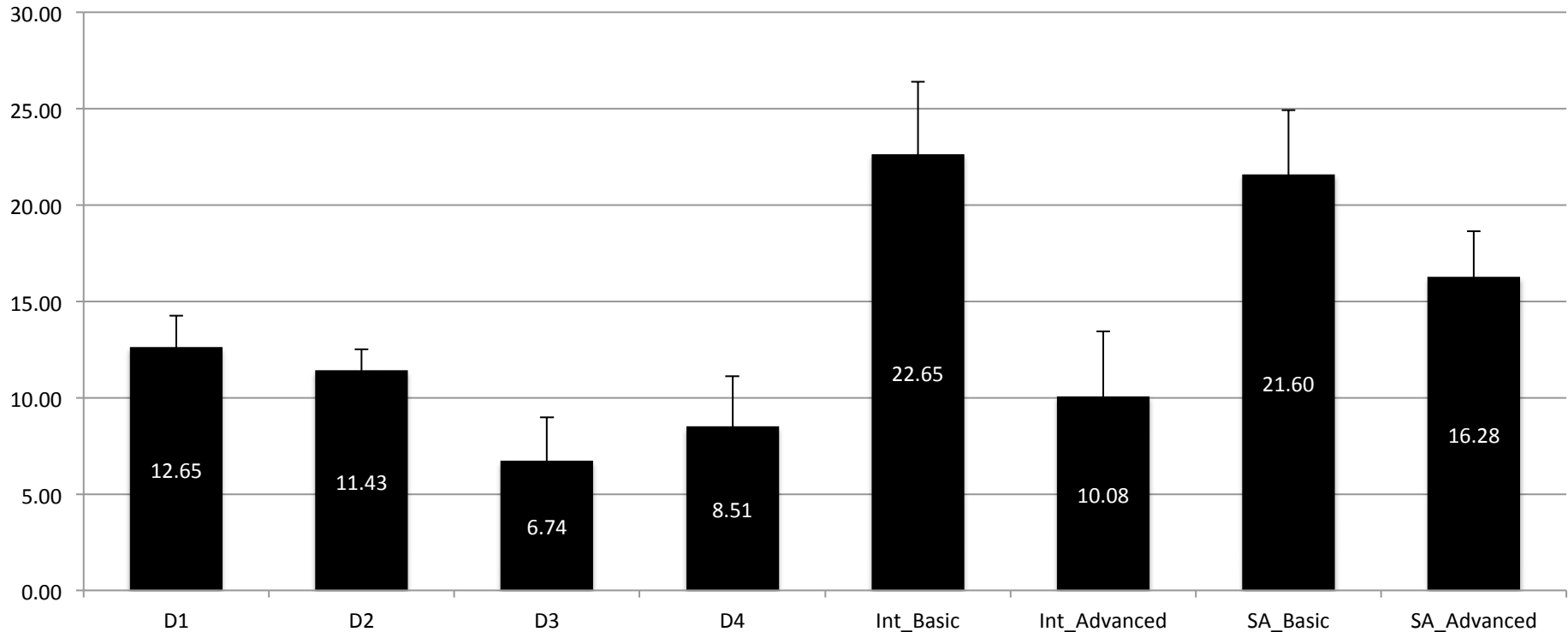
IHITL and PT4 Display Comparison

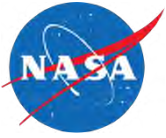




# Total Edit Time

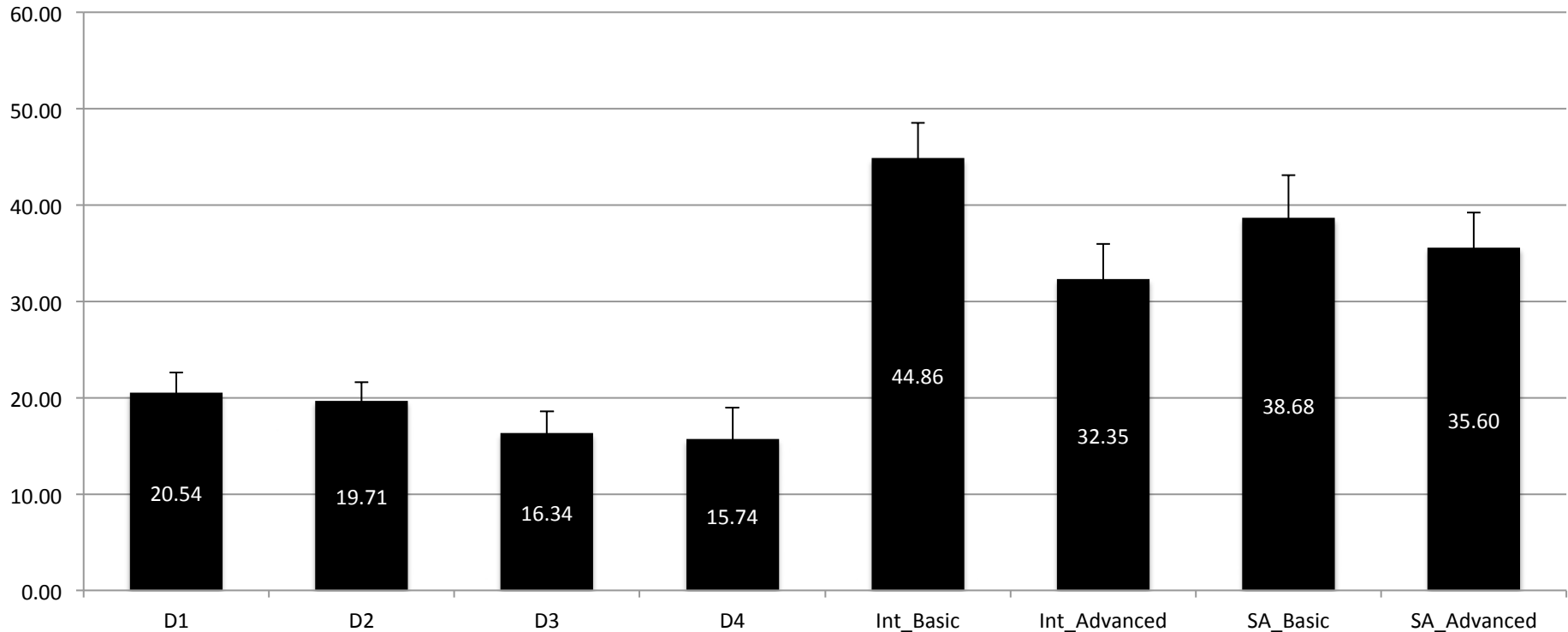
## IHITL and PT4 Display Comparison





# Total Response Time

## IHITL and PT4 Display Comparison

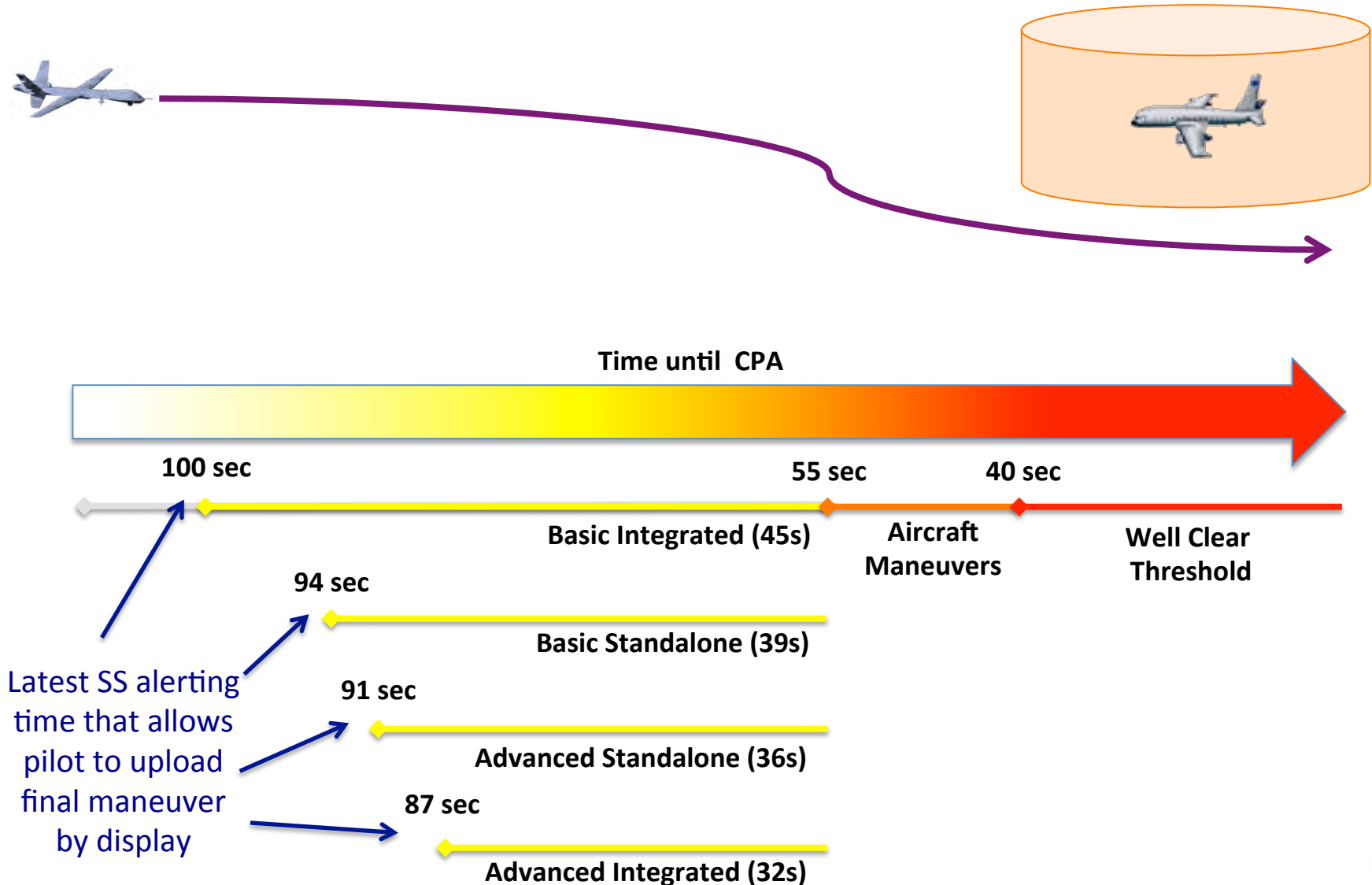


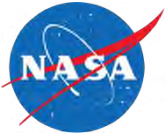




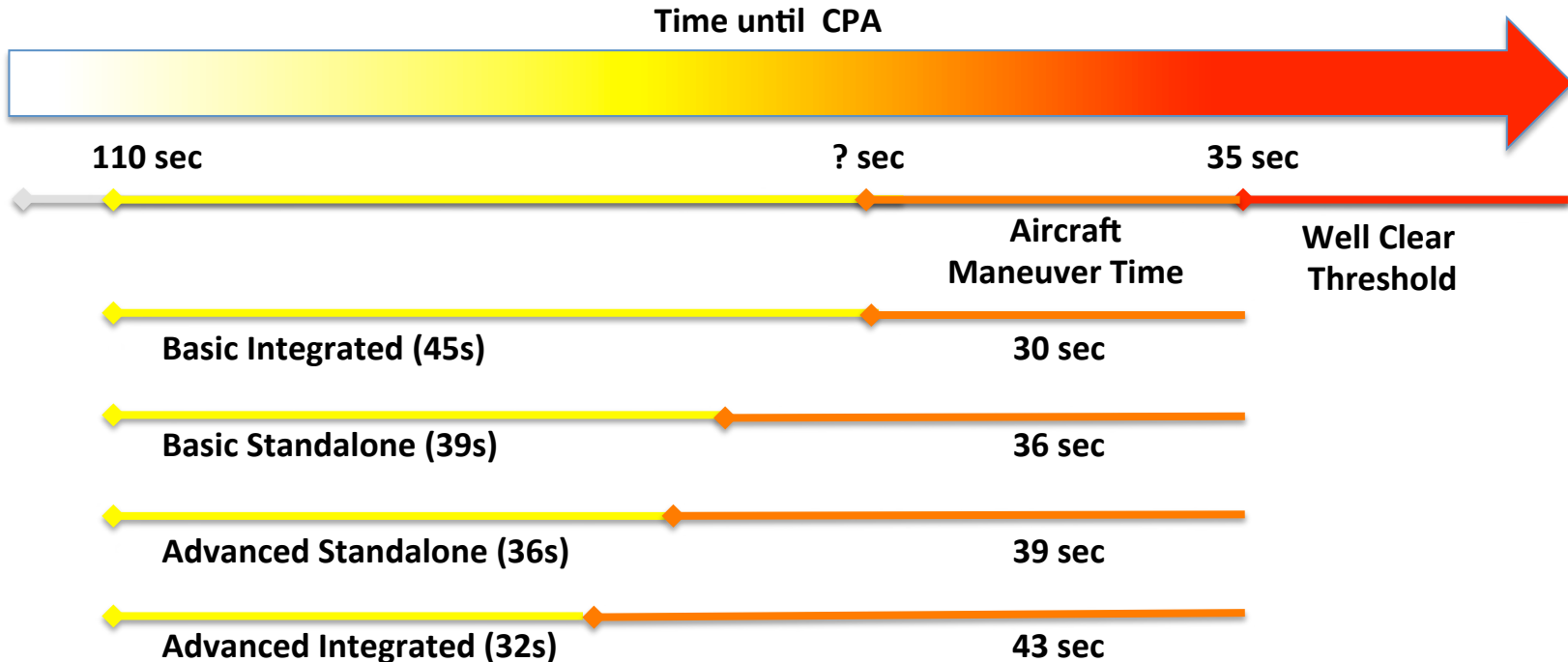


# Self-Separation Timeline



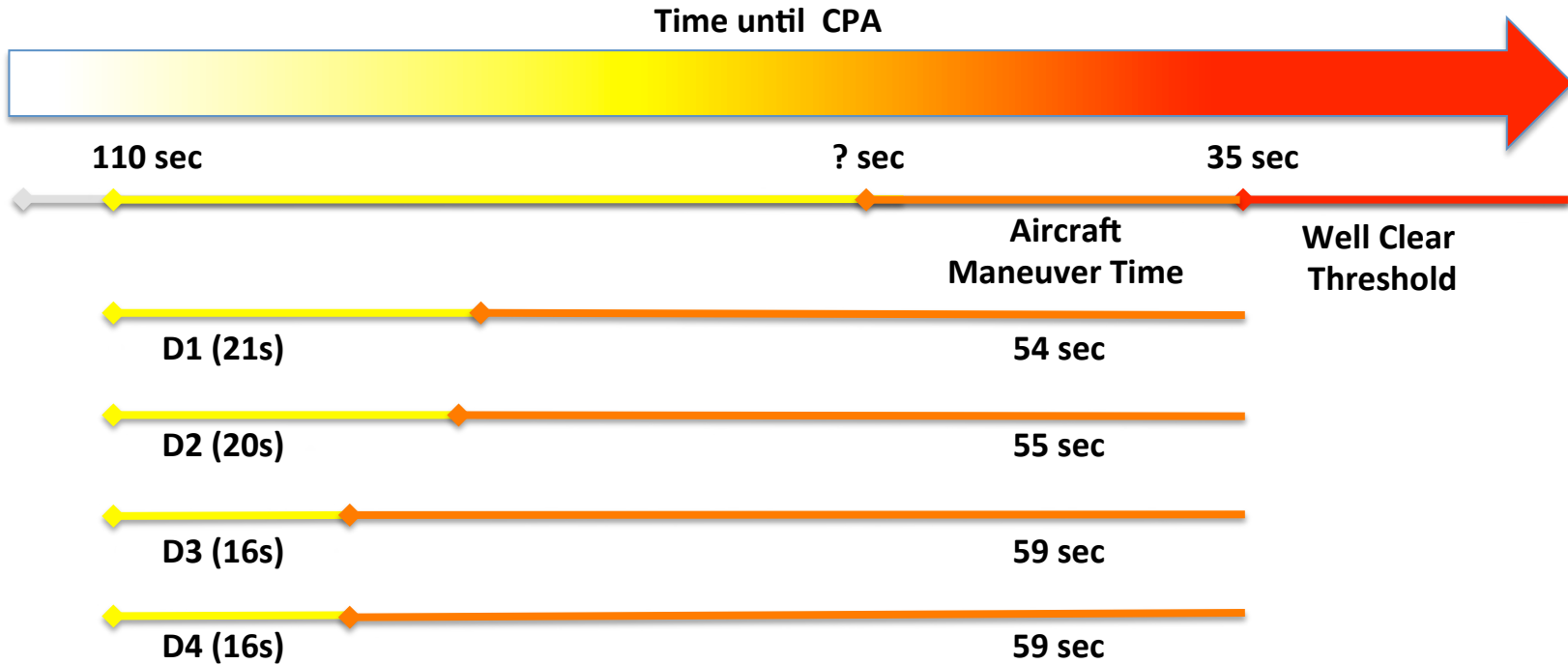


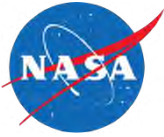
# Self-Separation Timeline





# Self-Separation Timeline



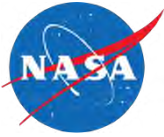


# DAA Task



- What does the DAA Task add to pilot response times?
  - A number of subtasks:
    - Detect
    - Determine
    - Execute
- Can compare to pilot response times when responding to ATC clearances in same navigation mode (AutoPilot; full mission simulation)
  - Assumption that ATC response is near immediate
  - Auto resolution conditions (D3 and D4) actually *reduce* edit times

Measure	FM AP Mean	iHITL Grand Mean	Difference
Initial RT	1.23s	8.25s	<b>+7.02s</b>
Initial Edit Time	9.11s	6.29s	<b>-2.82s</b>
Total Edit Time	9.25s	9.83s	<b>+0.58s</b>
Aircraft RT	10.43s	14.54s	<b>+4.11s</b>



# HSI Follow on Research

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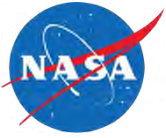


- Part Task Simulation 5
  - Goal: Continue examining DAA display concepts
    - Revisit a minimum information display condition – PT4 Basic with predictive alert level
    - Evaluate suggestive and informative displays
    - Evaluate effect of nominal uncertainty on displays and pilot performance
  - Data Collection March 2014

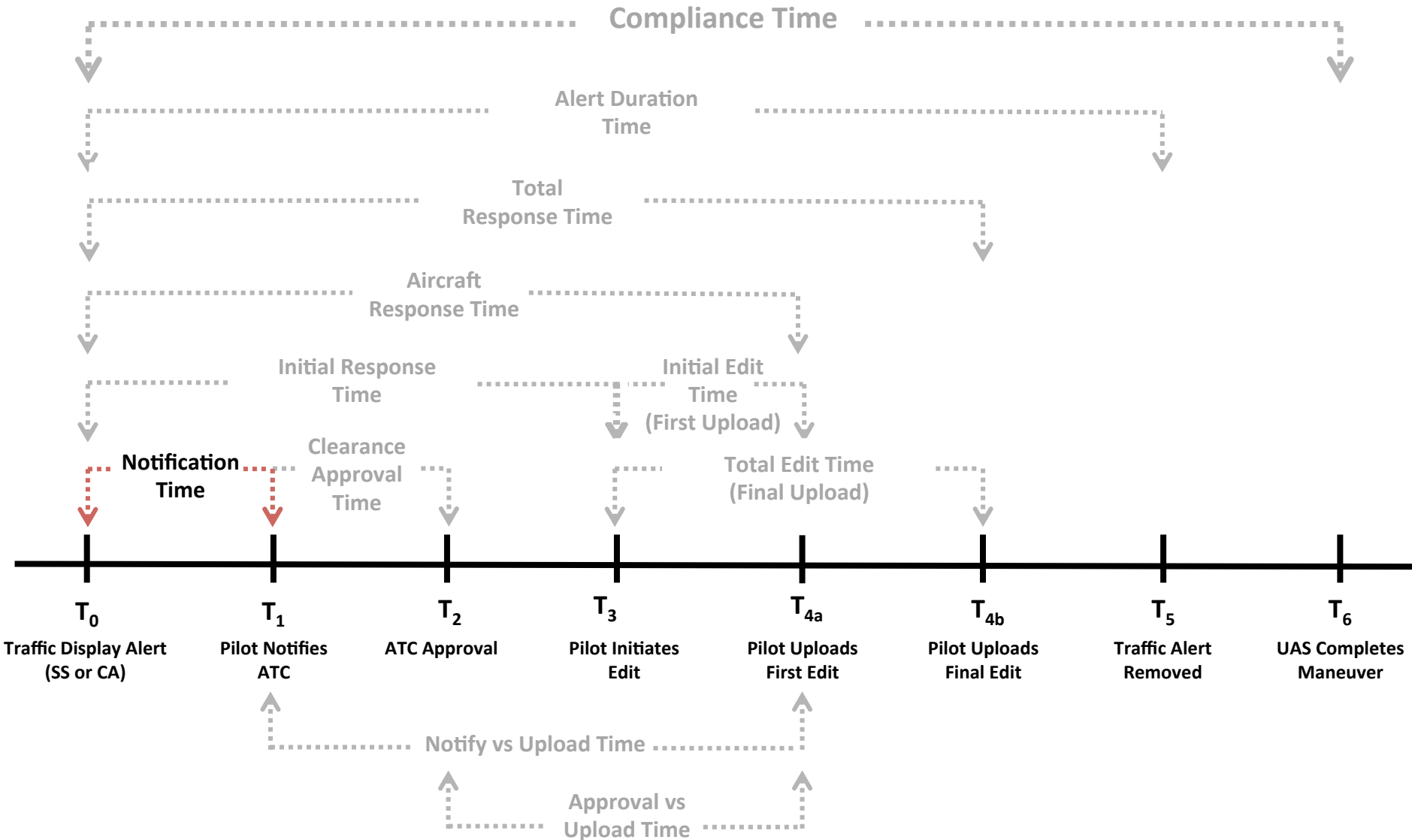




# All Results Slides

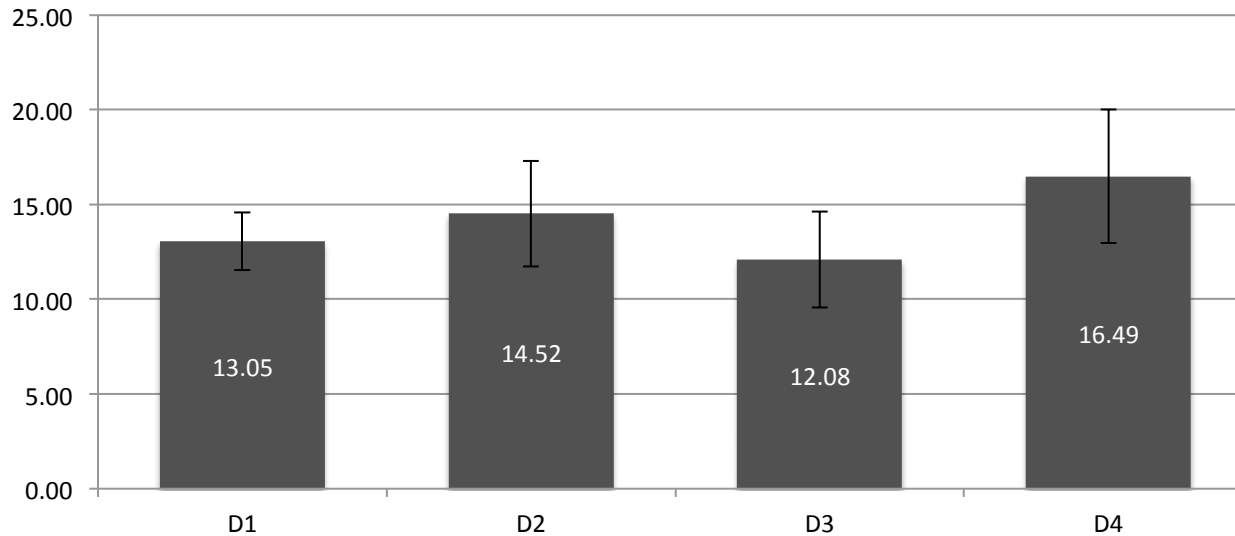


# Stages of Pilot DAA Task





# ATC Notification Time



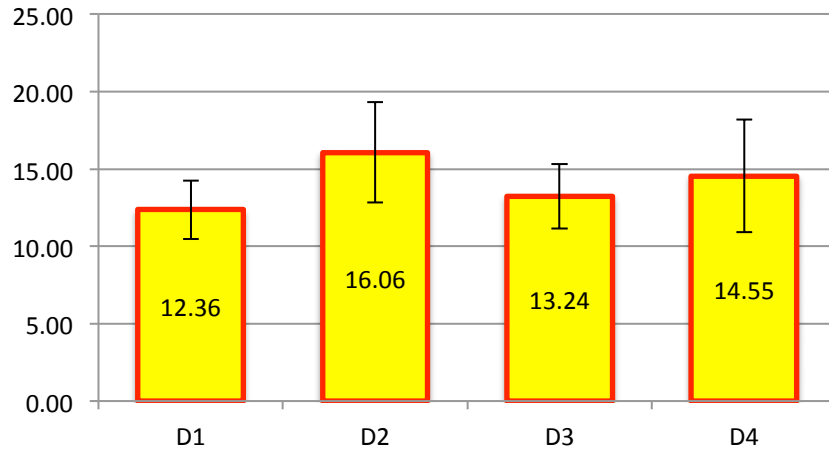
- There was not a significant main effect of Display on ATC Notification Time for all SS alerts,  $p > .05$
- Pilots took an average of **14.03 seconds** to notify ATC of a maneuver in response to a SS alert



# ATC Notification Time

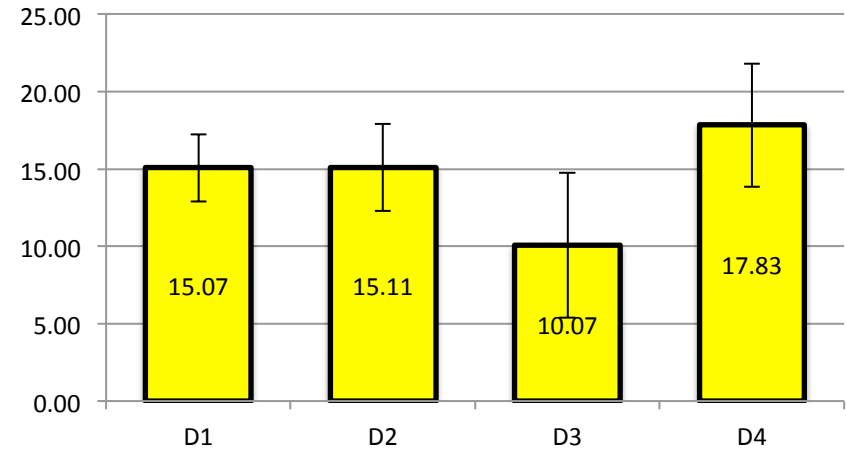


## Predictive SS Alerts



- There was no significant effect of Display on ATC Notification Time for Predictive SS alerts,  $p > .05$
- Pilots took an average of **14.05 seconds** to notify ATC of a maneuver in response to a Predictive SS alert

## Non-Predictive SS Alerts



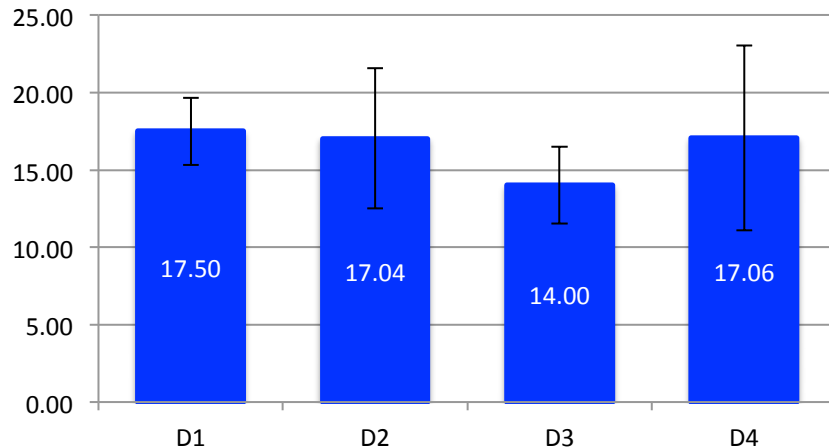
- There was no significant effect of Display on ATC Notification Time for Non-Predictive SS alerts,  $p > .05$
- Pilots took an average of **14.52** to notify ATC of a maneuver in response to a Non-Predictive SS alert



# ATC Notification Time

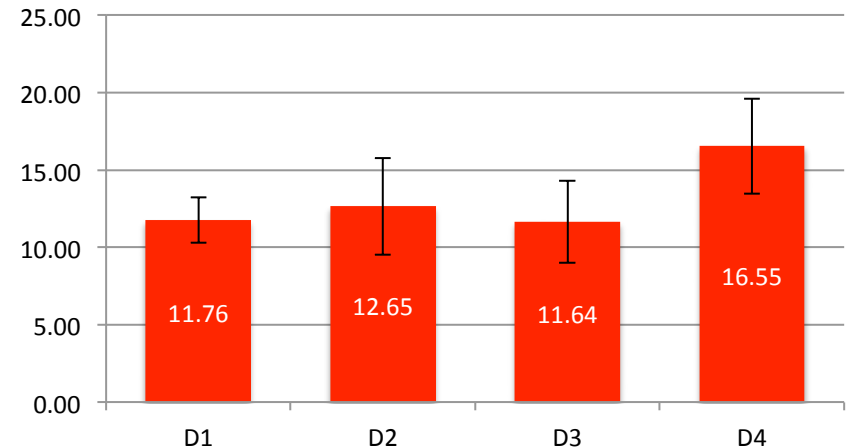


## Cooperative SS Alerts



- There was no significant effect of Display on ATC Notification Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **16.40 seconds** to notify ATC of a maneuver in response to a Cooperative SS alert

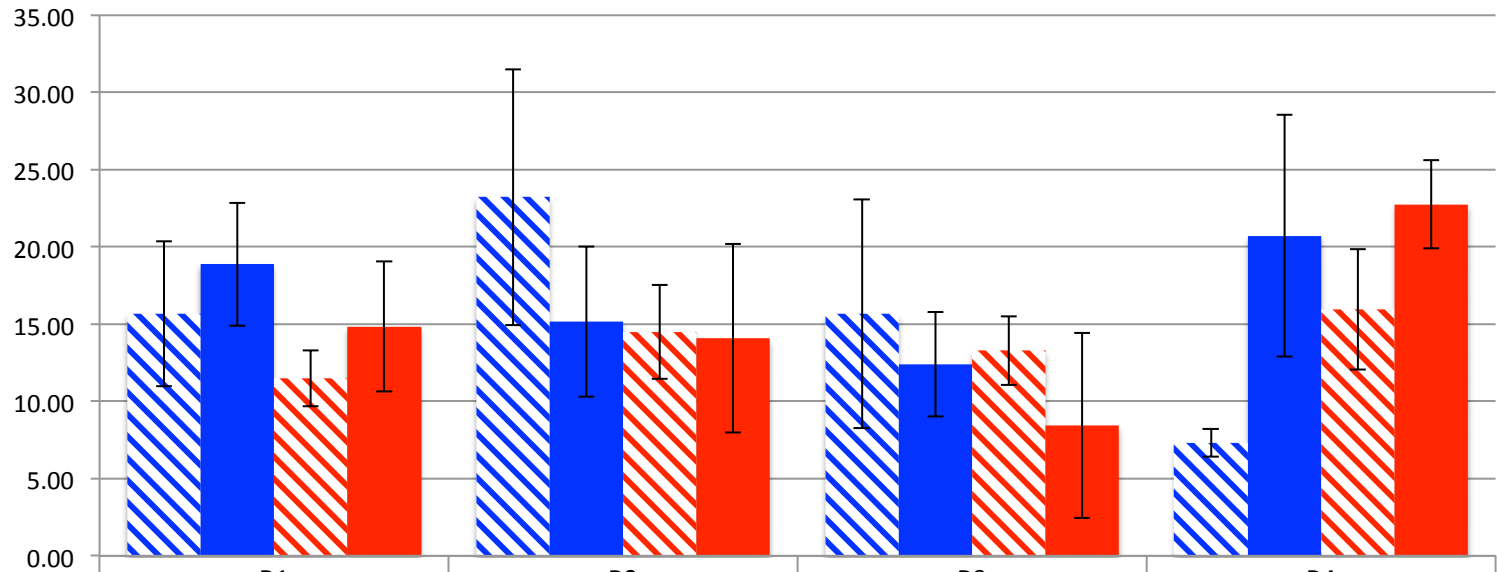
## Non-Cooperative SS Alerts



- There was no significant effect of Display on ATC Notification Time for Non-Cooperative SS alerts,  $p > .05$
- Pilots took an average of **13.15 seconds** to notify ATC of a maneuver in response to a Non-Cooperative SS alert



# ATC Notification Time

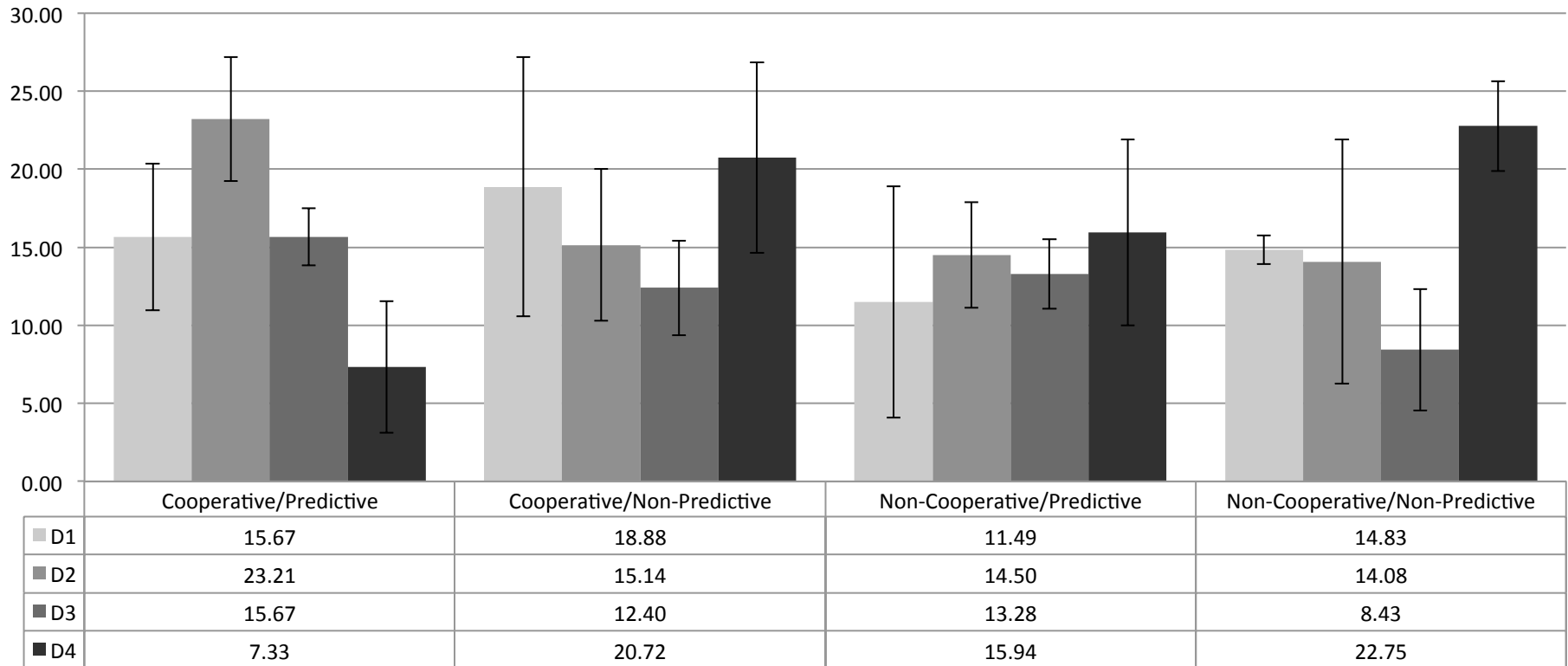


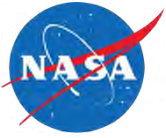
Cooperative/Predictive	D1	15.67	D2	23.21	D3	15.67	D4	7.33
Cooperative/Non-Predictive		18.88		15.14		12.40		20.72
Non-Cooperative/Predictive		11.49		14.50		13.28		15.94
Non-Cooperative/Non-Predictive		14.83		14.08		8.43		22.75





# ATC Notification Time

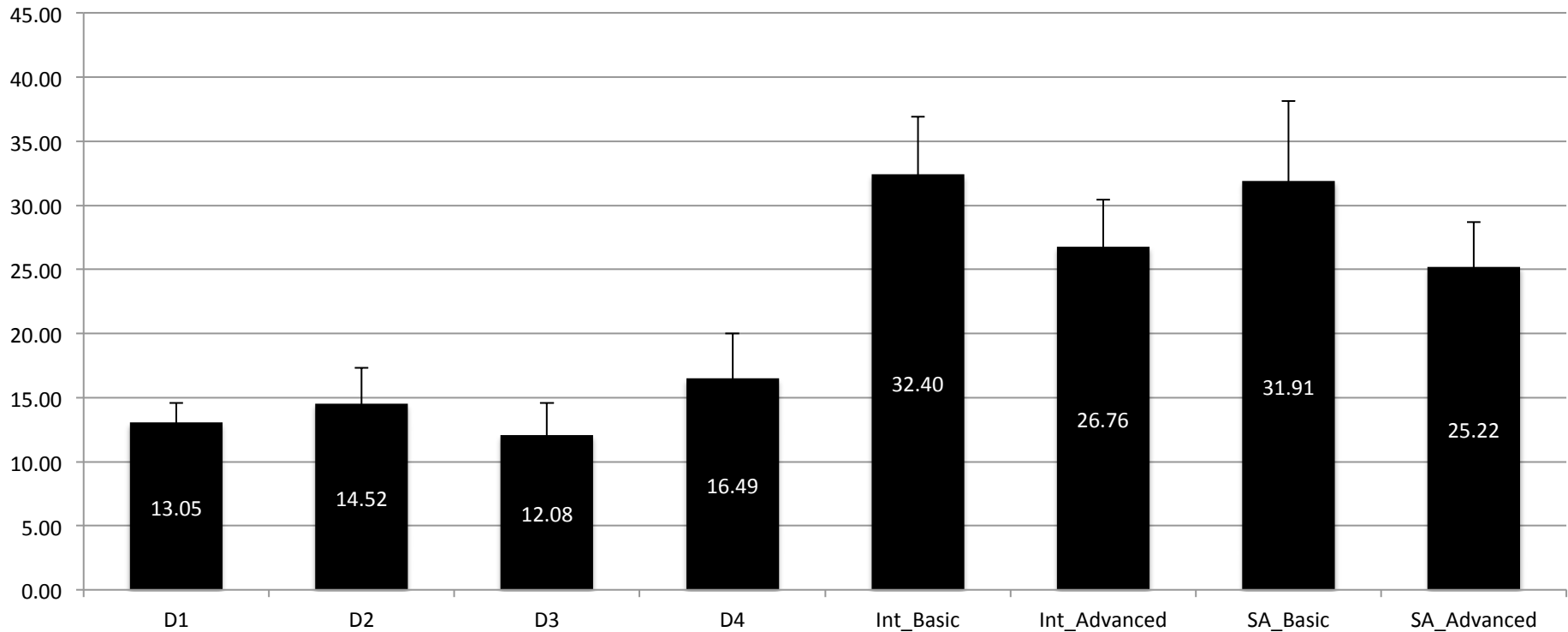


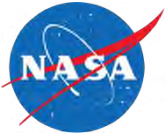


# ATC Notification Time

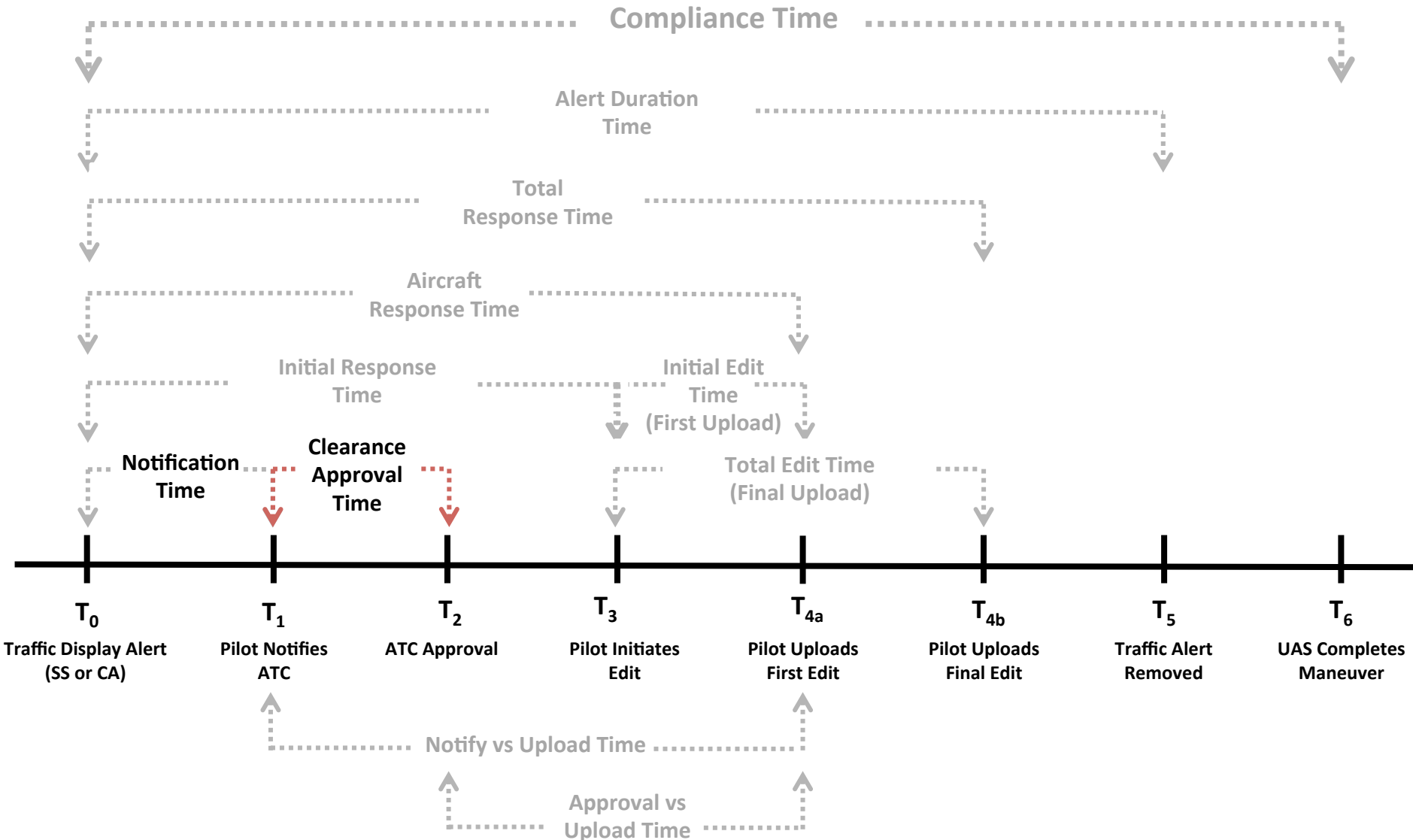


## IHITL and PT4 Display Comparison



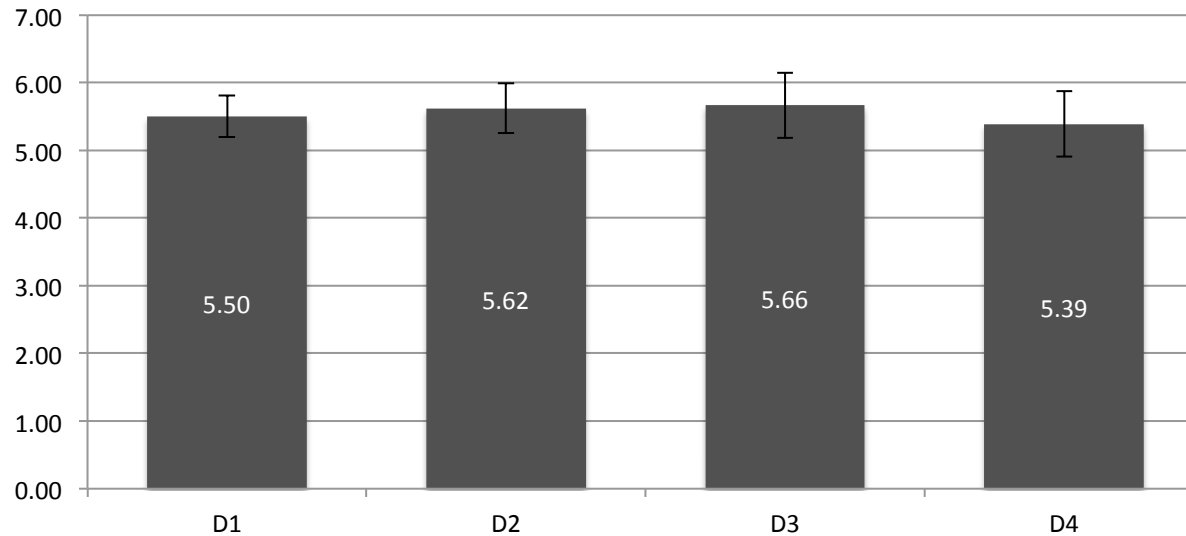


# Stages of Pilot DAA Task

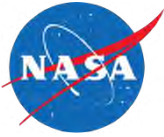




# Clearance Approval Time



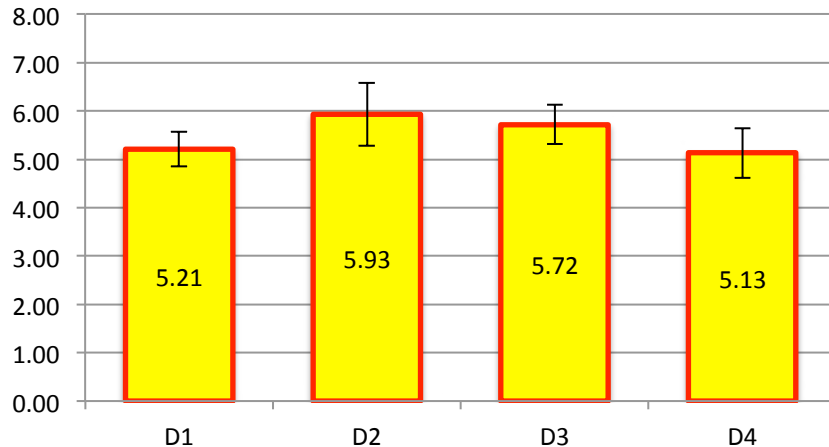
- There was no significant main effect of Information on Clearance Approval Time,  $p > .05$
- It took an average of **5.54 seconds** for pilots to receive and an ATC approval for a maneuver in response to a SS alert



# Clearance Approval Time

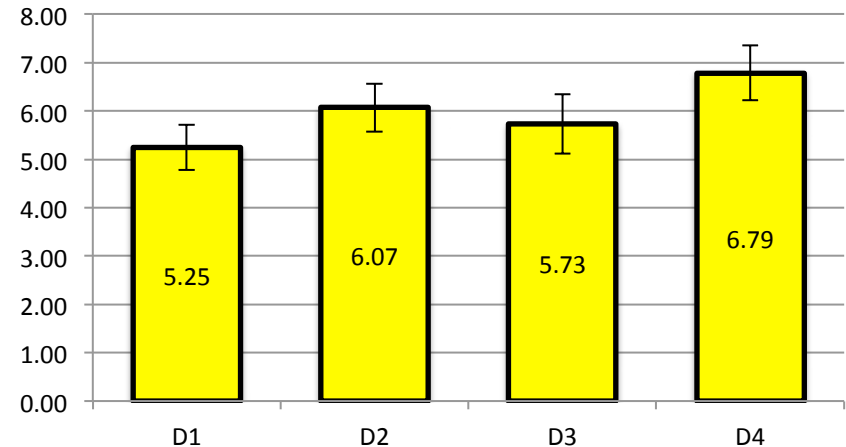


## Predictive SS Alerts

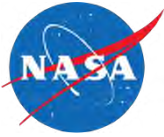


- There was no significant main effect of Information on Clearance Approval Time,  $p > .05$
- It took an average of **5.50 seconds** for pilots to receive and an ATC approval for a maneuver in response to a Predictive SS alert

## Non-Predictive SS Alerts



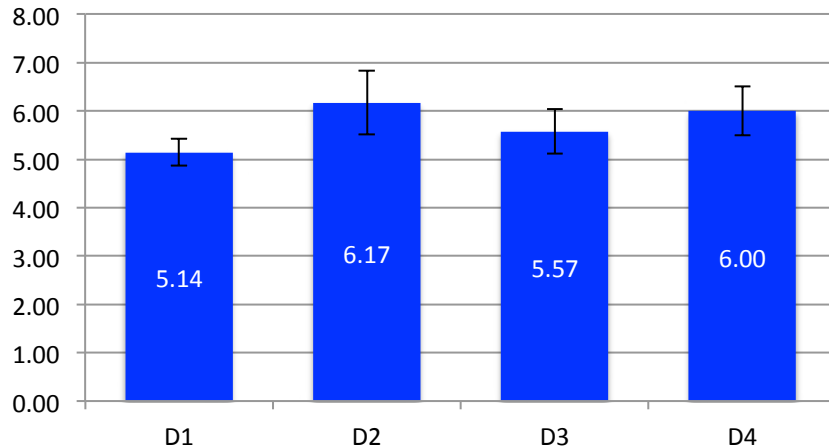
- There was no significant main effect of Display on Clearance Approval Time,  $p > .05$
- It took an average of **5.96 seconds** for pilots to receive and an ATC approval for a maneuver in response to a Non-Predictive SS alert



# Clearance Approval Time

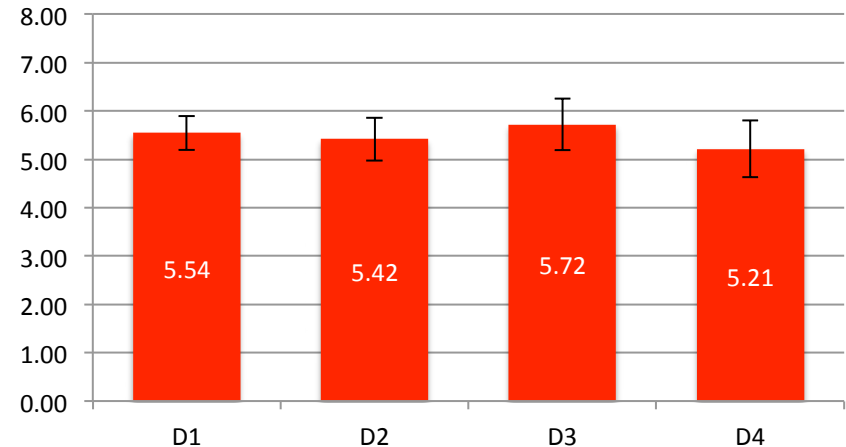


## Cooperative SS Alerts



- There was not a significant effect of Display on Clearance Approval Time for Cooperative SS alerts,  $p > .05$
- It took an average of **5.72 seconds** for pilots to receive and an ATC a Cooperative SS alert

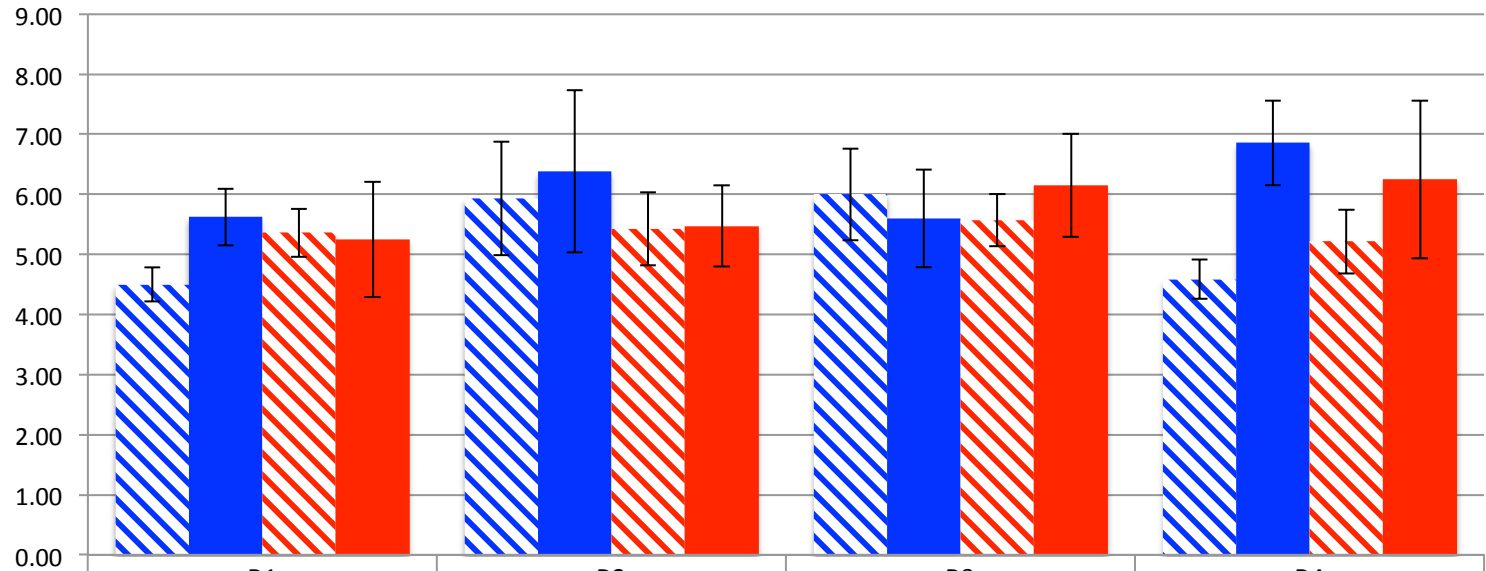
## Non-Cooperative SS Alerts



- There was no significant effect of Display on Clearance Approval Time for Non-Cooperative SS alerts,  $p > .05$
- It took an average of **5.47 seconds** for pilots to receive and an ATC approval for a maneuver in response to a Non-Cooperative SS alert



# Clearance Approval Time

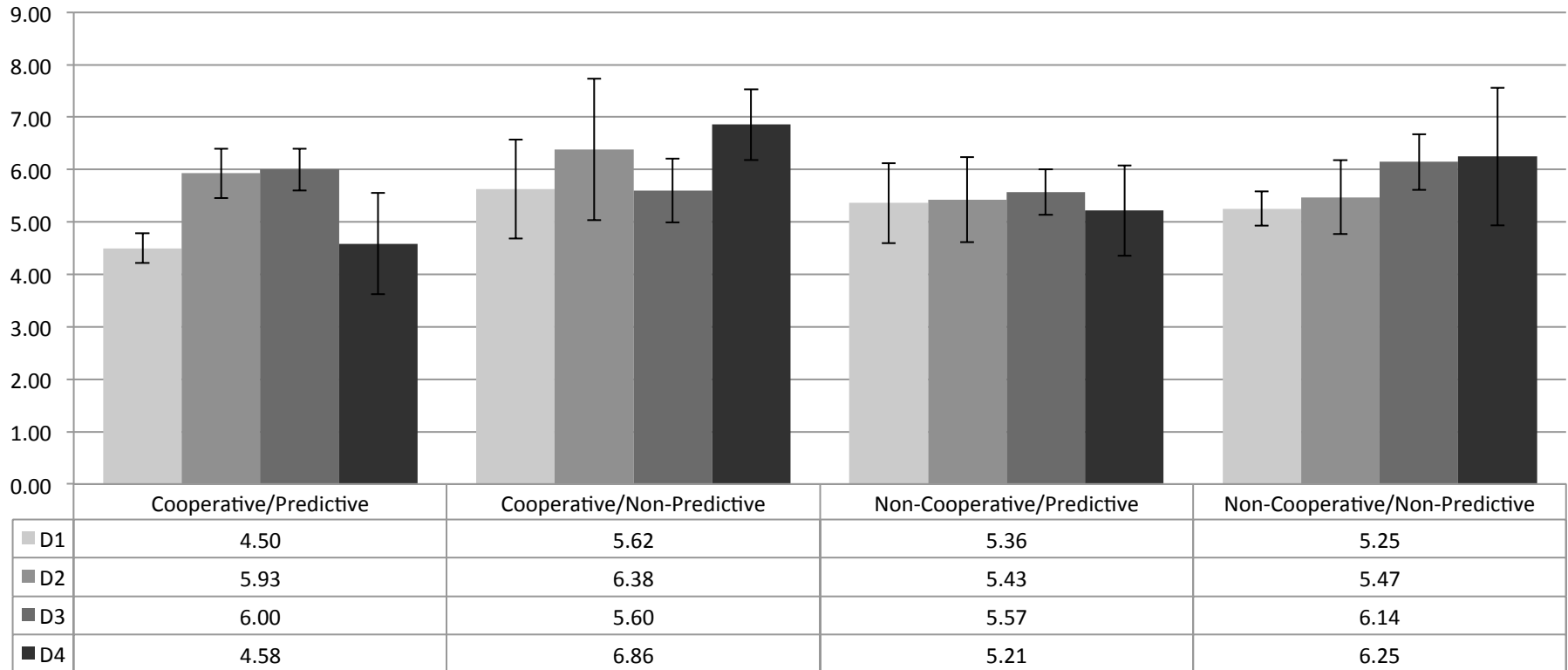


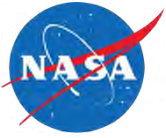
Cooperative/Predictive	D1	D2	D3	D4
Cooperative/Non-Predictive	4.50	5.93	6.00	4.58
Non-Cooperative/Predictive	5.62	6.38	5.60	6.86
Non-Cooperative/Non-Predictive	5.36	5.43	5.57	5.21
	5.25	5.47	6.14	6.25





# Clearance Approval Time

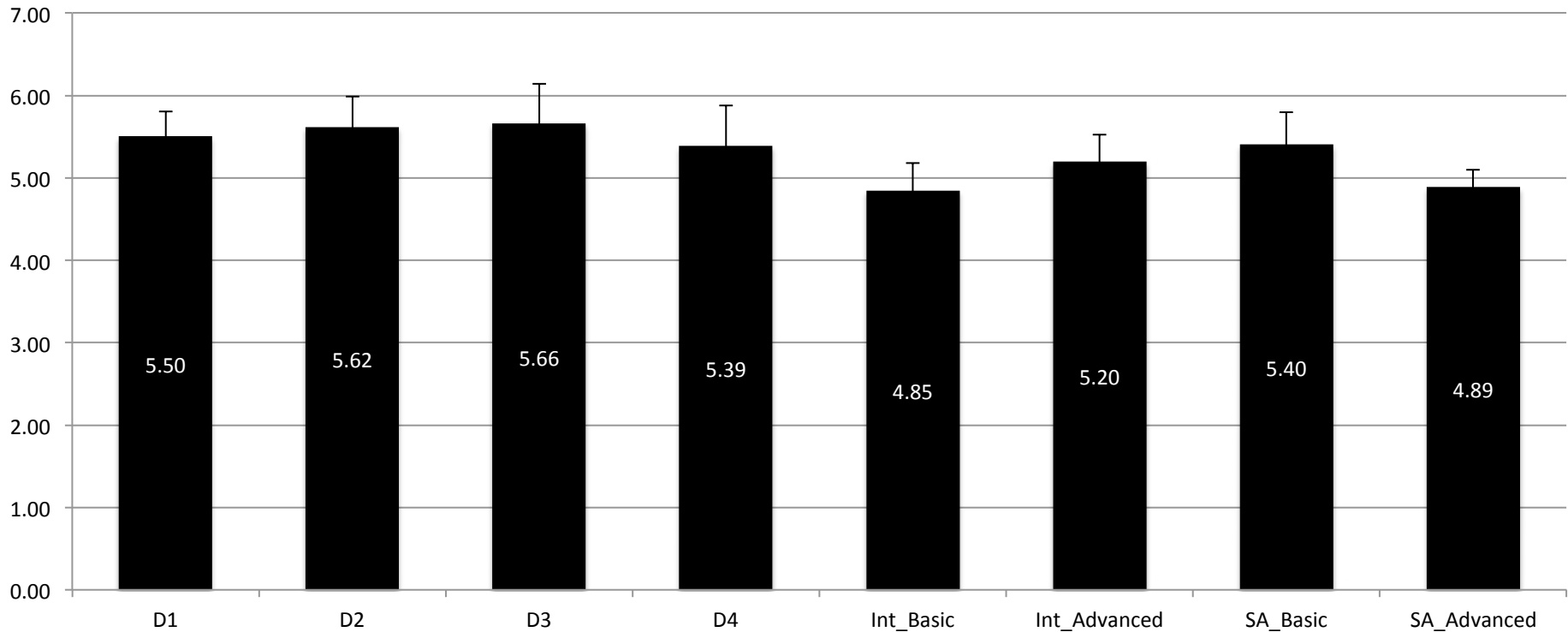


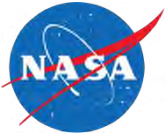


# Clearance Approval Time

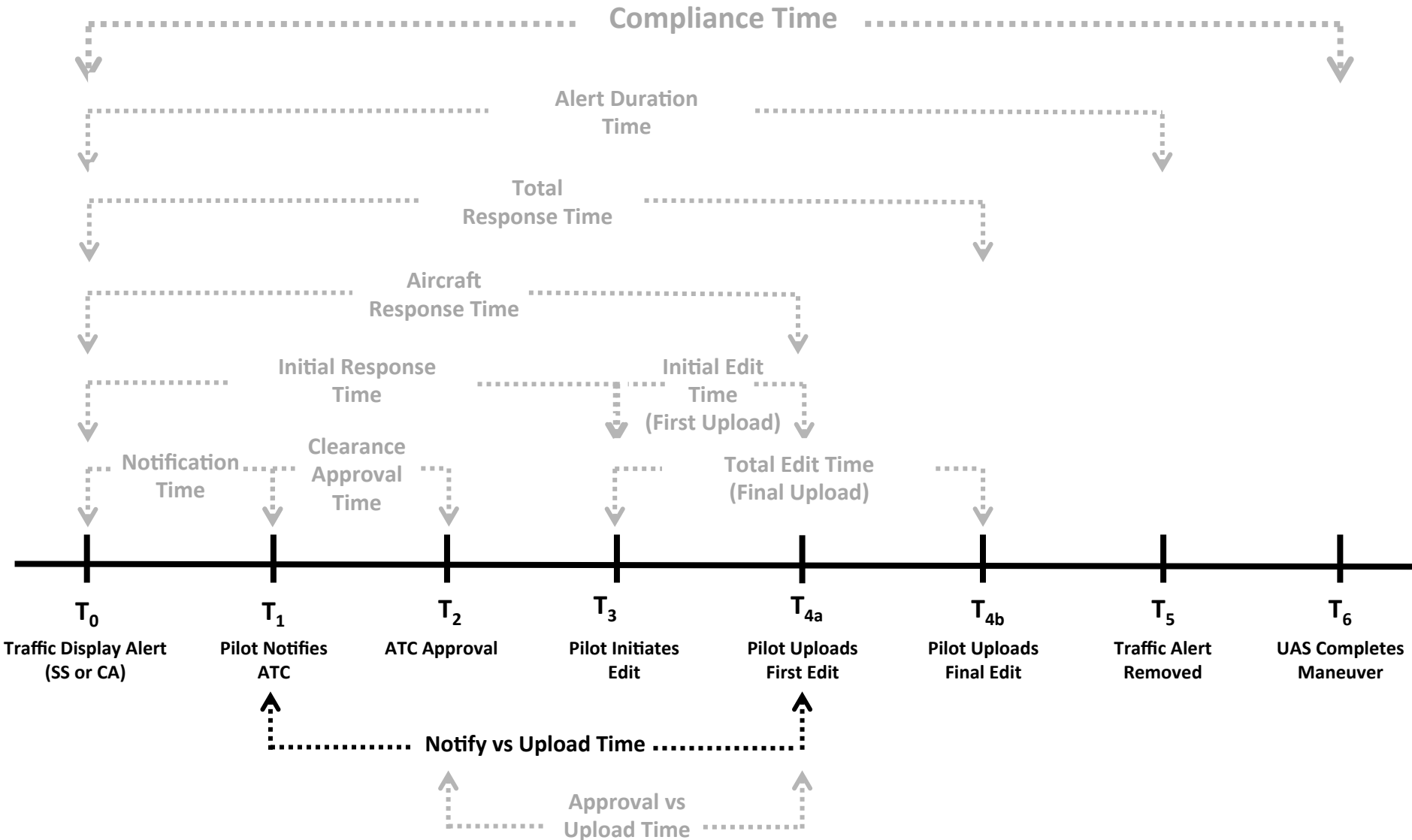


IHITL and PT4 Display Comparison



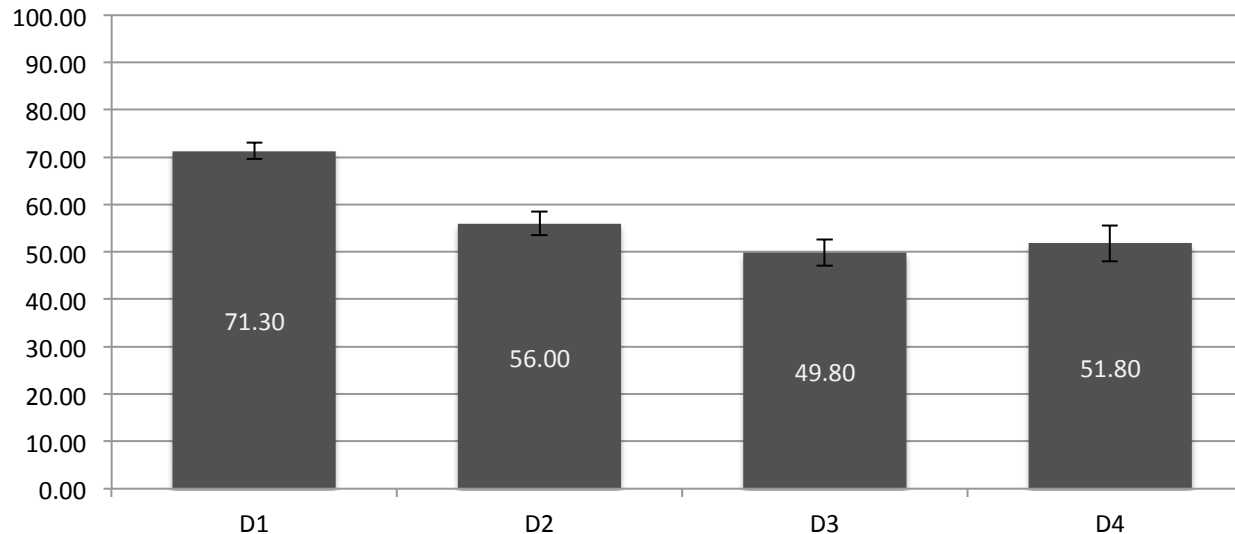


# Stages of Pilot DAA Task

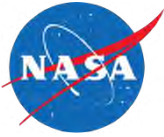




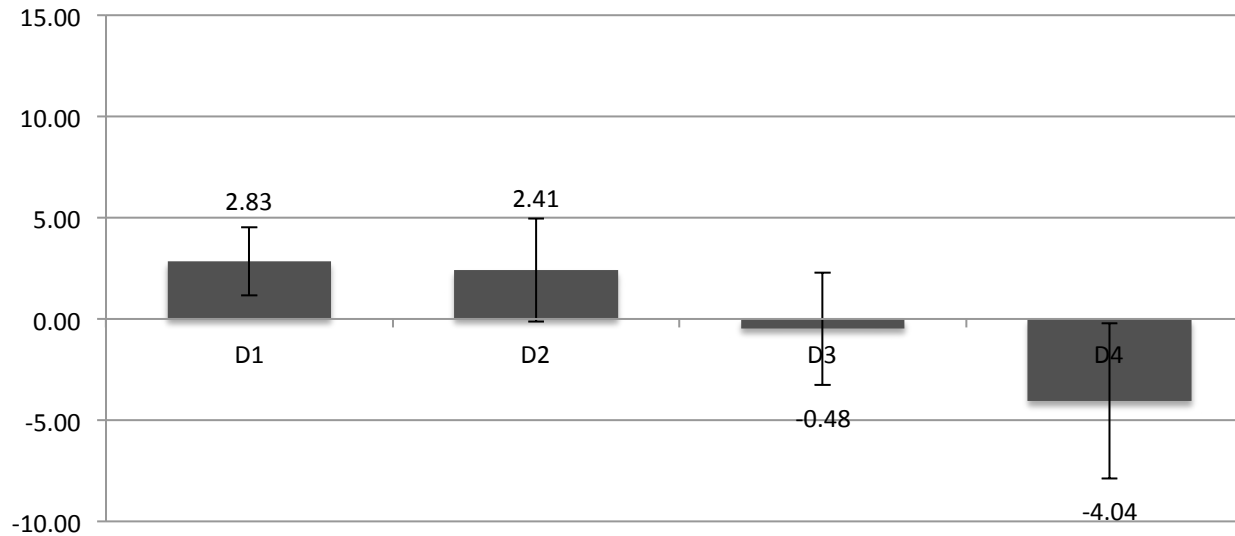
# ATC Notification vs Upload Time



- Across all maneuvers, pilots requested a clearance **93.4%** of the time
- On average, pilots who *requested* an ATC clearance did so prior to maneuvering in response to SS alerts **57.2%** of the time (65.1% overall)
  - D1 = 71.3%
  - D2 = 56.0%
  - D3 = 49.8%
  - D4 = 51.8%



# ATC Notification vs Upload Time



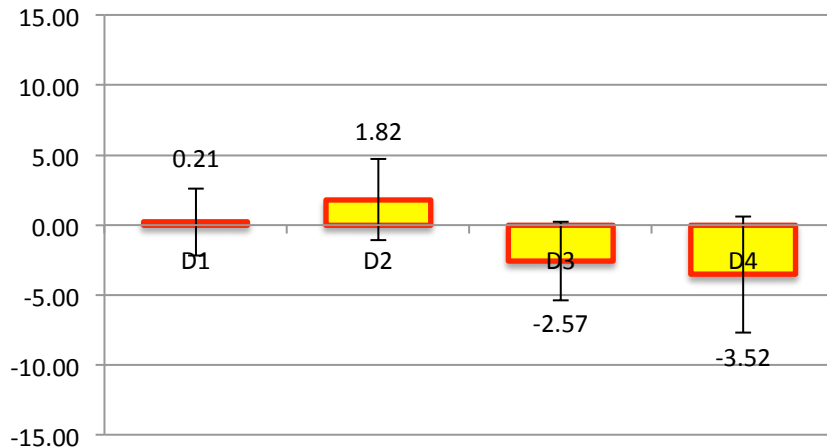
- There was a near significant effect of Display on ATC Notification vs Upload Time for all SS alerts,  $p = .075$
- On average, pilots *requested* an ATC clearance **0.18 seconds prior** to uploading a maneuver in response to a Predictive SS alert



# ATC Notification vs Upload Time

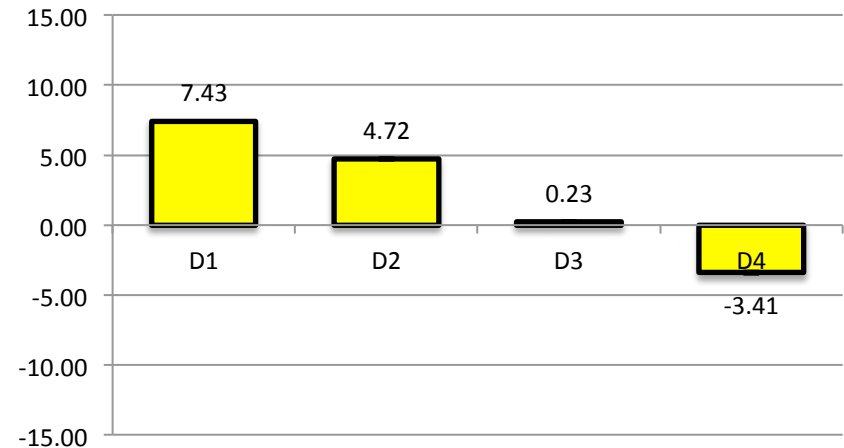


## Predictive SS Alerts



- There was no significant effect of Display on ATC Notification vs Upload Time for Predictive SS alerts,  $p > .05$
- On average, pilots *requested* an ATC clearance **1.01 sec after** uploading a maneuver in response to a Predictive SS alert

## Non-Predictive SS Alerts



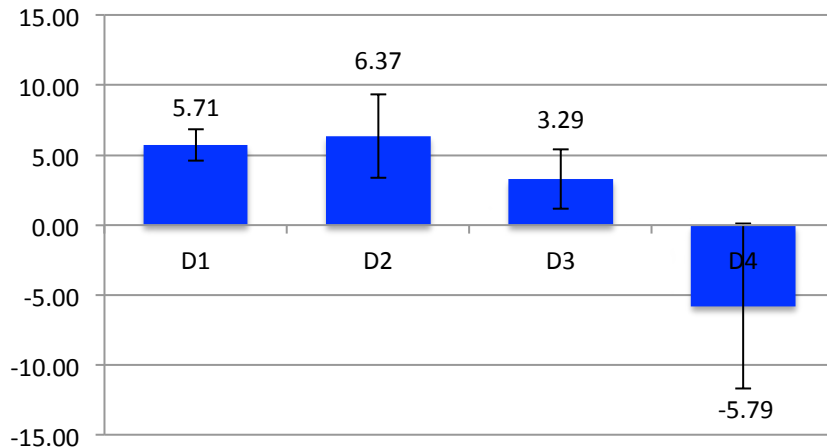
- There was a significant effect of Display on ATC Notification vs Upload Time for Non-Predictive SS alerts,  $p < .05$ 
  - No differences between displays were significant
- On average, pilots *requested* an ATC clearance **2.24 seconds prior** to uploading a maneuver in response to a Non-Predictive SS alert



# ATC Notification vs Upload Time

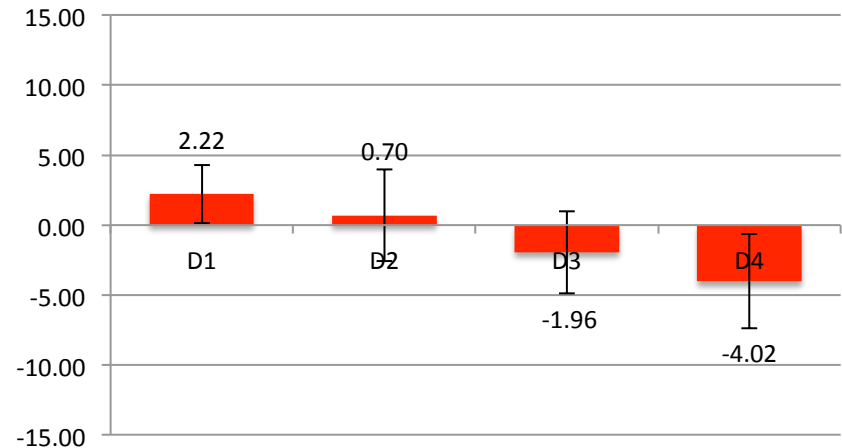


## Cooperative SS Alerts



- There was a near significant effect of Information on ATC Notification vs Upload Time for Cooperative SS alerts,  $p = .055$
- On average, pilots *requested* an ATC clearance **2.40 seconds prior** to uploading a maneuver in response to a Cooperative SS alert

## Non-Cooperative SS Alerts

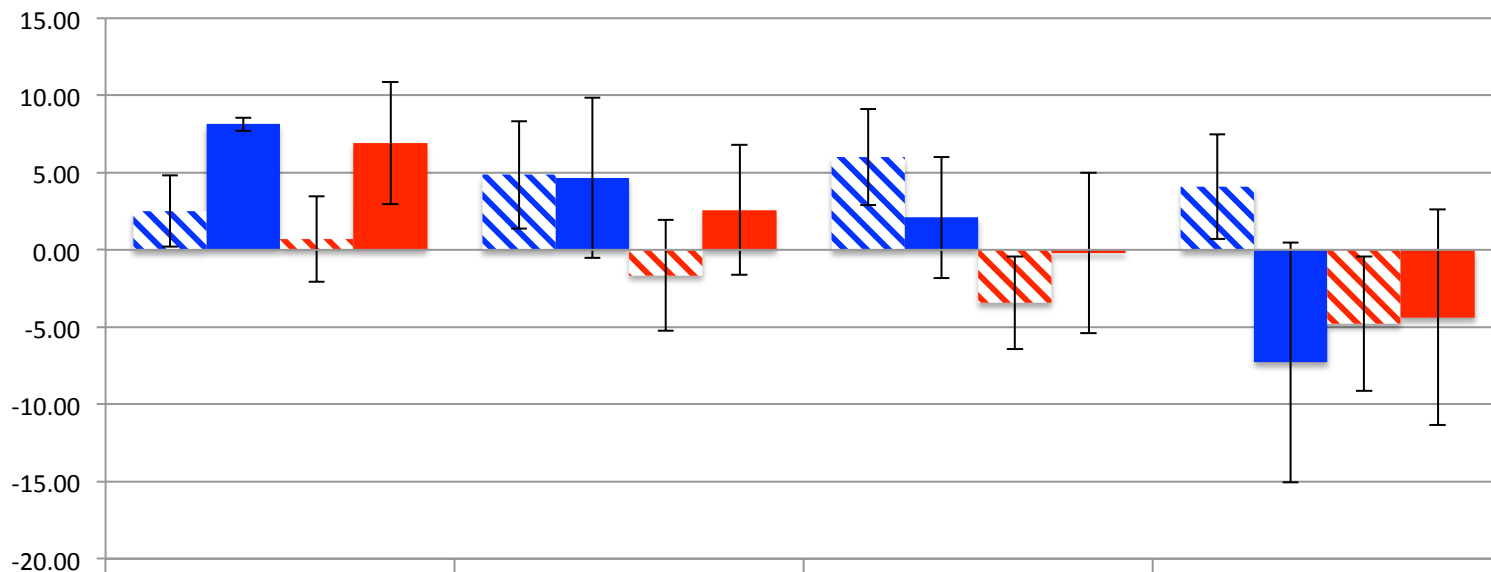


- There was no significant effect of Display on ATC Notification vs Upload Time for Non-Cooperative SS alerts,  $p > .05$
- On average, pilots *requested* an ATC clearance **0.76 seconds after** uploading a maneuver in response to a Non-Cooperative alert

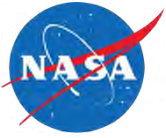




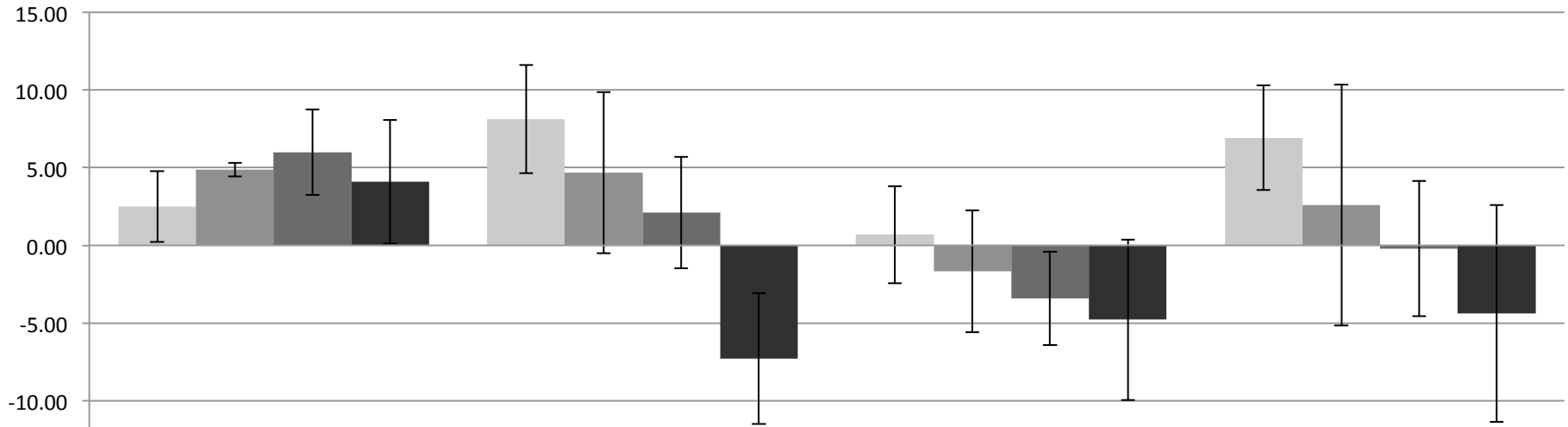
# ATC Notification vs Upload Time



	D1	D2	D3	D4
Cooperative/Predictive	2.50	4.86	6.00	4.08
Cooperative/Non-Predictive	8.13	4.67	2.10	-7.29
Non-Cooperative/Predictive	0.69	-1.66	-3.43	-4.79
Non-Cooperative/Non-Predictive	6.92	2.58	-0.21	-4.38



# ATC Notification vs Upload Time



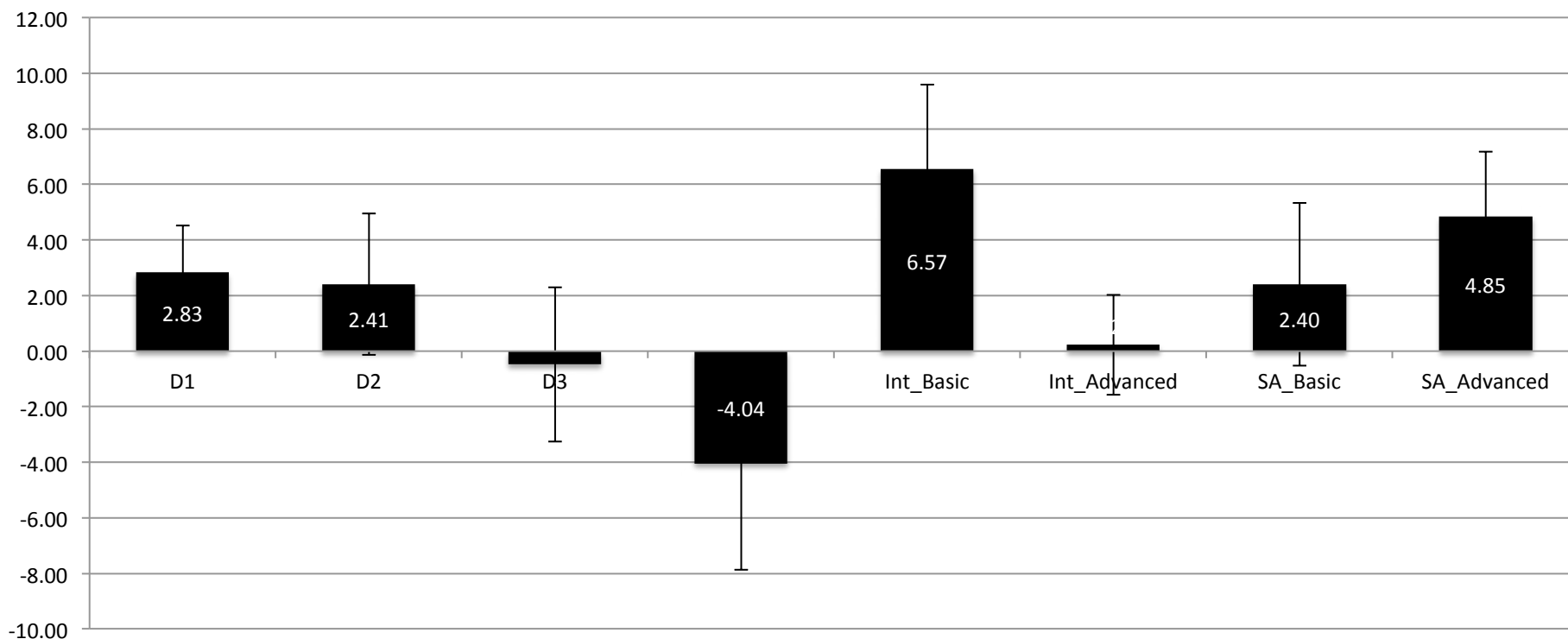
	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	2.50	8.13	0.69	6.92
D2	4.86	4.67	-1.66	2.58
D3	6.00	2.10	-3.43	-0.21
D4	4.08	-7.29	-4.79	-4.38



# ATC Notification vs Upload Time

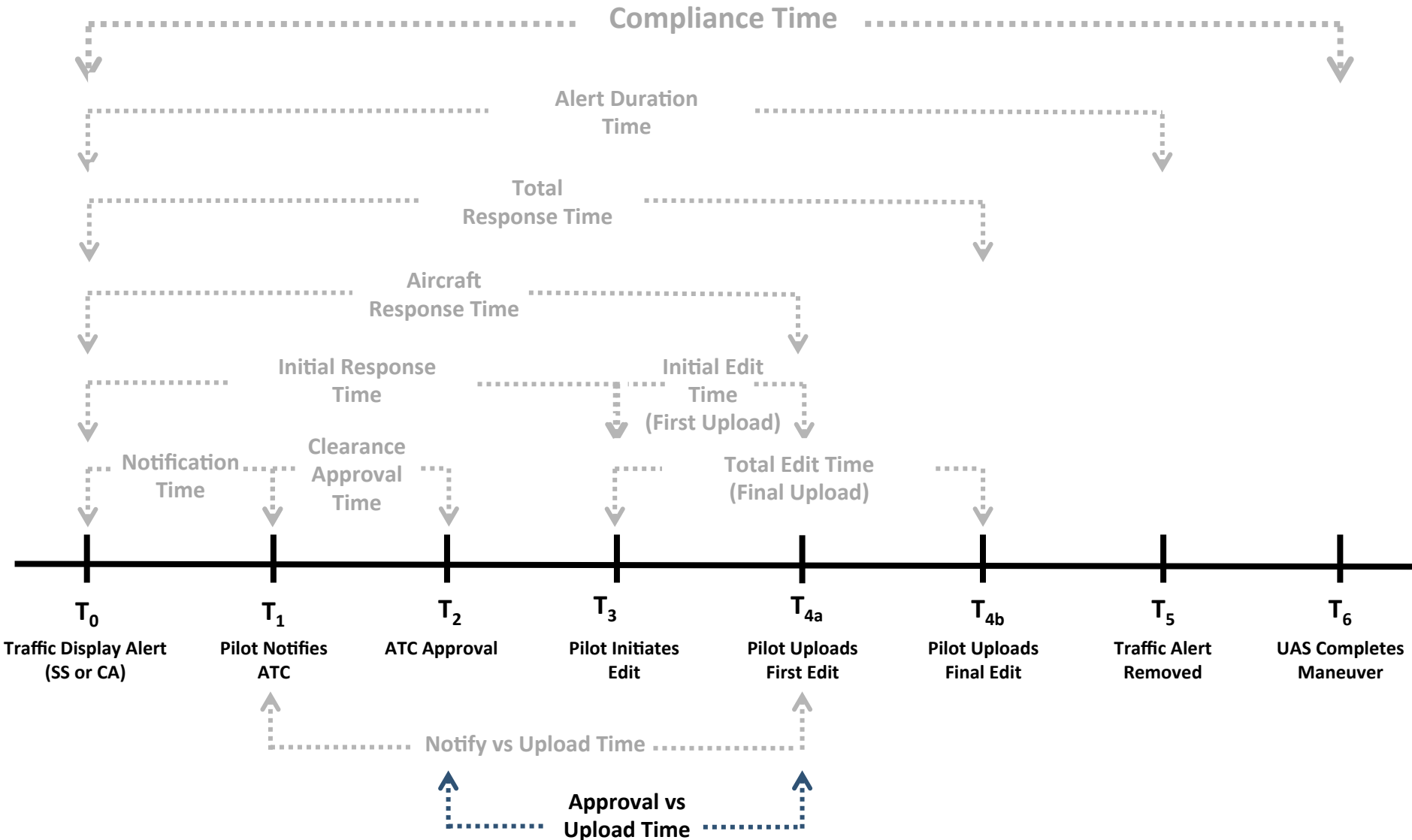


## IHITL and PT4 Display Comparison



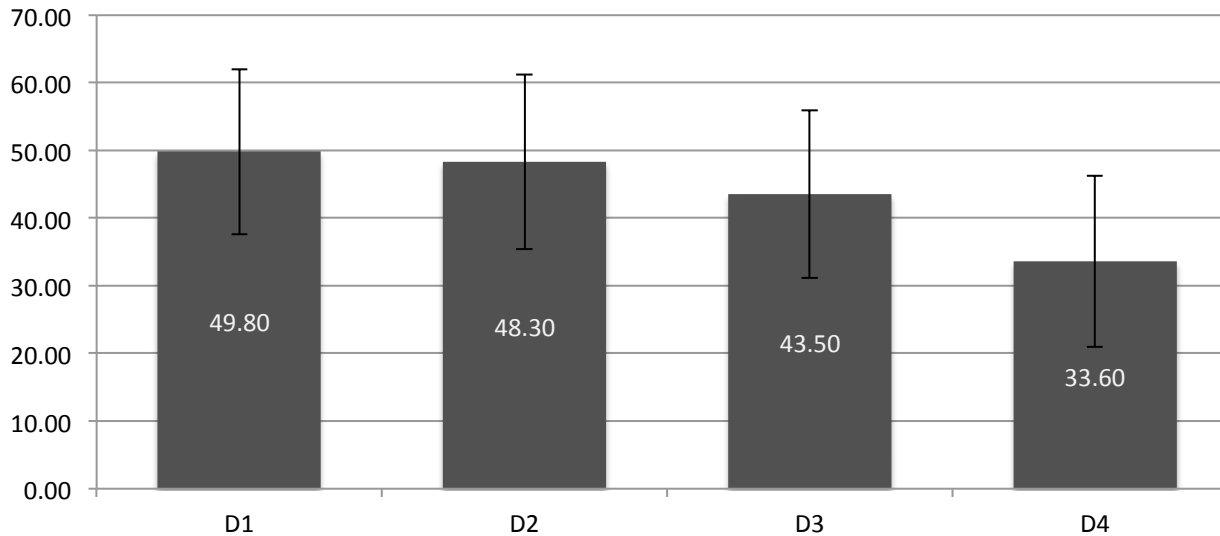


# Stages of Pilot DAA Task





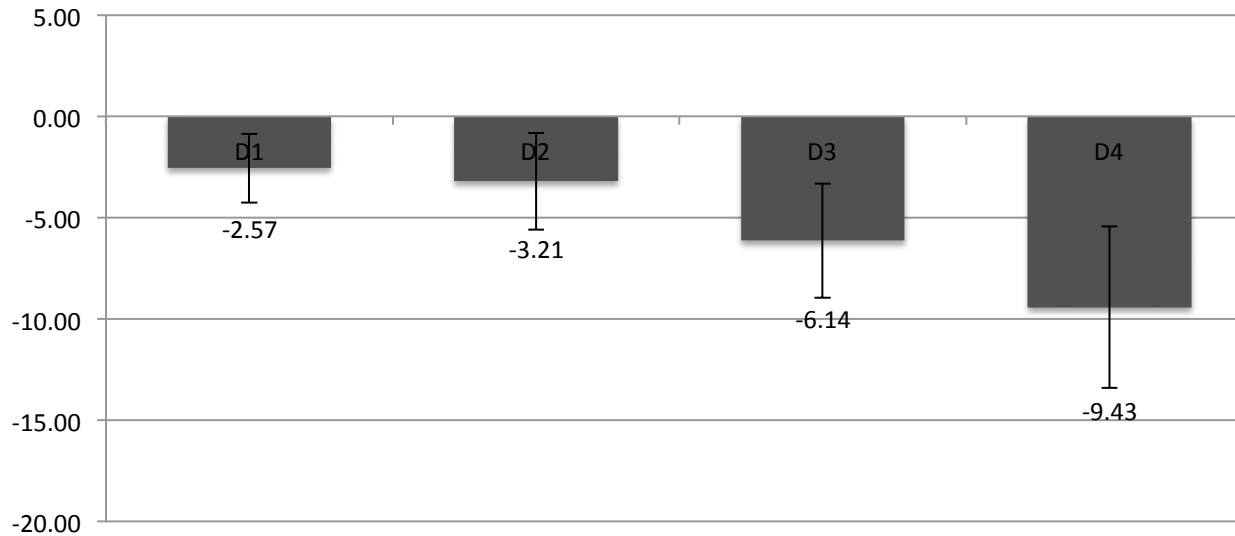
# ATC Approval vs Upload Time



- Across all maneuvers, pilots received a clearance **92.9%** of the time
- On average, pilots who *received* an ATC clearance, did so prior to maneuvering in response to SS alerts **56.2%** of the time (62.8% overall)
  - D1 = 49.8%
  - D2 = 48.3%
  - D3 = 43.5%
  - D4 = 33.6%



# ATC Approval vs Upload Time



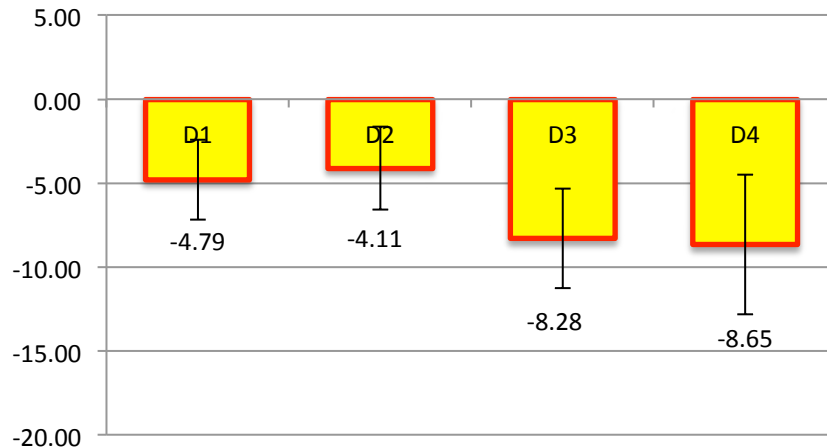
- There was a near significant effect of Display on ATC Approval vs Upload Time for all SS alerts,  $p = .092$
- On average, pilots *received* an ATC clearance **6.46 seconds after** uploading a maneuver in response to a Predictive SS alert



# ATC Approval vs Upload Time

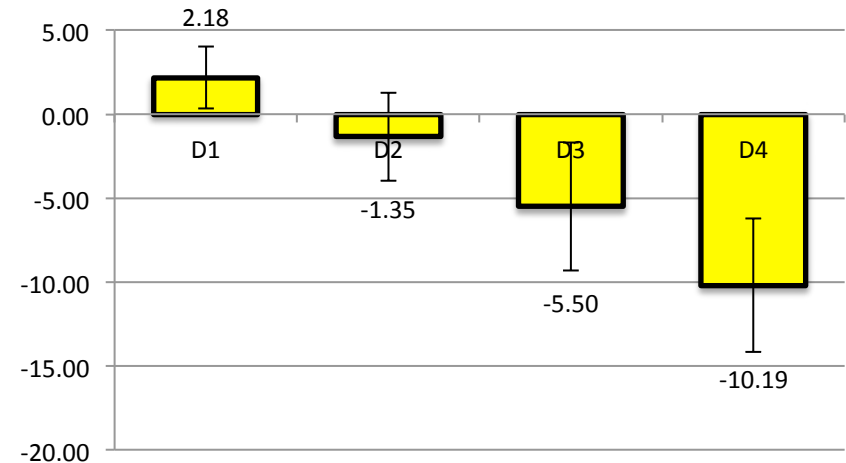


## Predictive SS Alerts

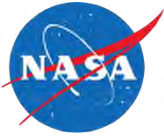


- There was no significant effect of Display on ATC Approval vs Upload Time for Predictive SS alerts,  $p > .05$
- On average, pilots *received* an ATC clearance **6.46 seconds after** uploading a maneuver in response to a Predictive SS alert

## Non-Predictive SS Alerts



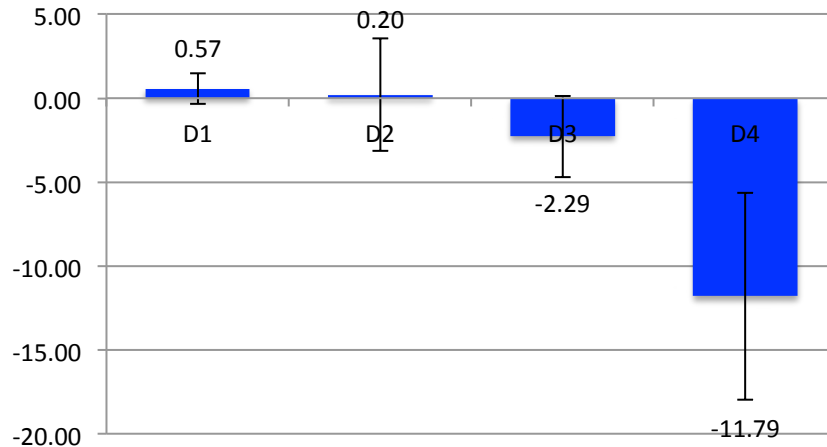
- There was a significant effect of Display on ATC Approval vs Upload Time for Non-Predictive SS alerts,  $p < .05$ 
  - No differences between displays were significant
- On average, pilots *received* an ATC clearance **3.71 seconds after** uploading a maneuver in response to a Non-Predictive SS alert



# ATC Approval vs Upload Time

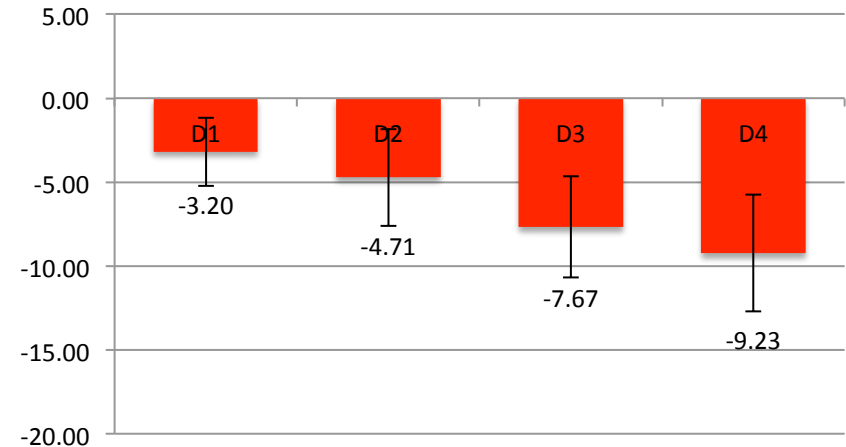


## Cooperative SS Alerts



- There was a near significant effect of Display on ATC Approval vs Upload Time for Cooperative SS alerts,  $p = .070$
- On average, pilots *received* an ATC clearance **3.33 seconds after** uploading a maneuver in response to a Cooperative SS alert

## Non-Cooperative SS Alerts

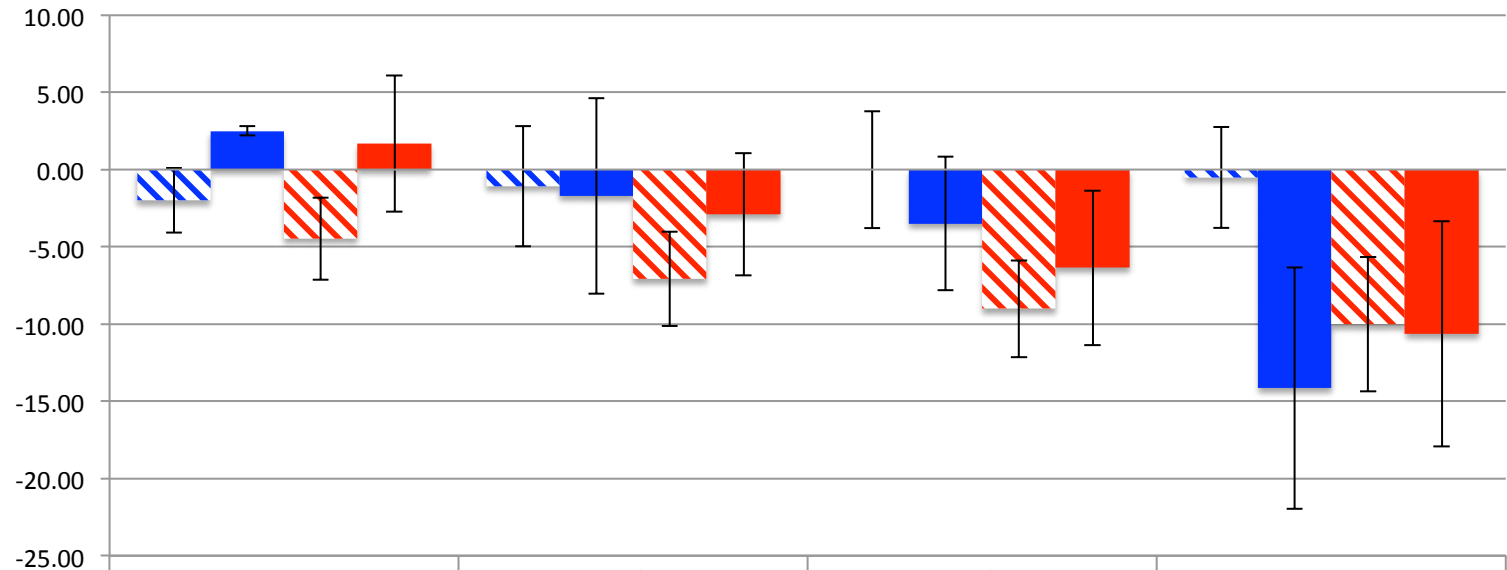


- There was no significant effect of Display on ATC Approval vs Upload Time for Non-Cooperative SS alerts,  $p > .05$
- On average, pilots *received* an ATC clearance **6.20 seconds after** uploading a maneuver in response to a Non-Cooperative SS alert

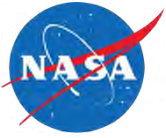




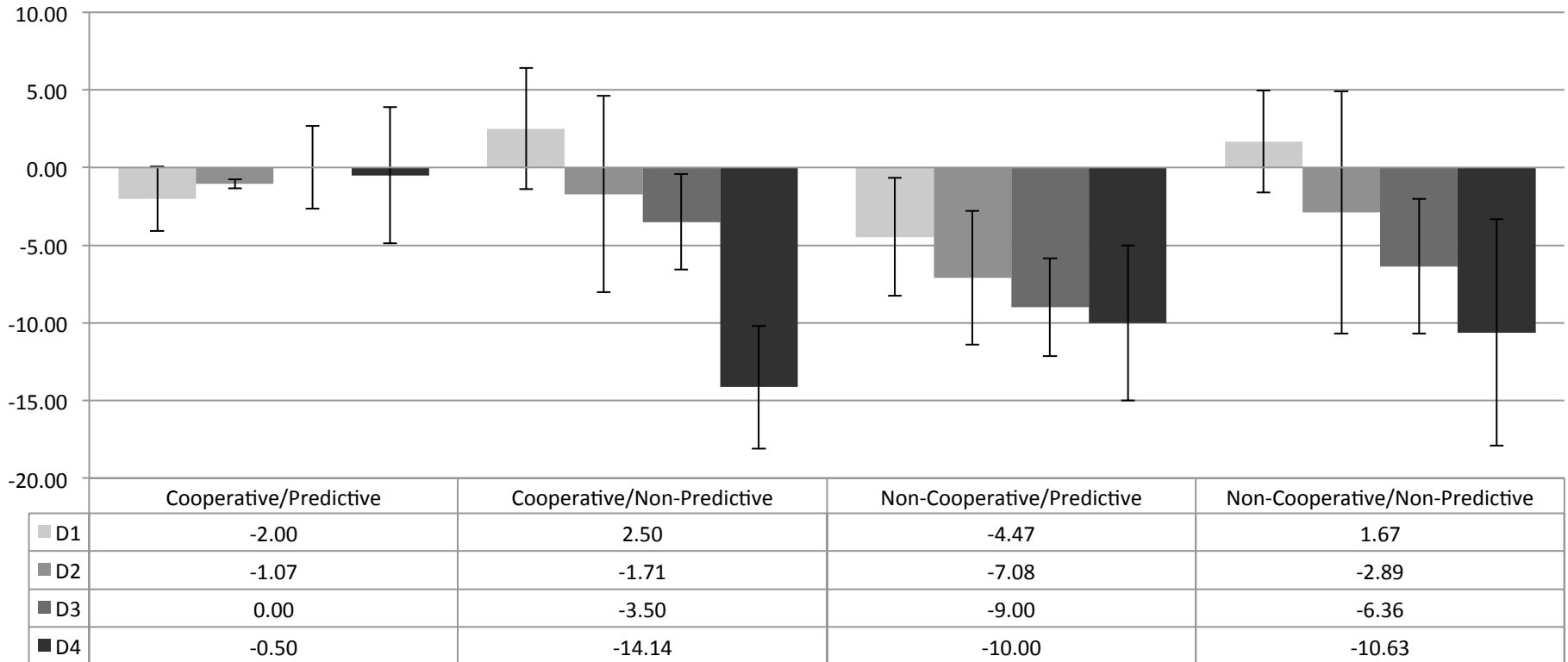
# ATC Approval vs Upload Time

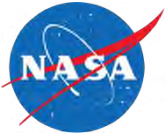


	D1	D2	D3	D4
Cooperative/Predictive	-2.00	-1.07	0.00	-0.50
Cooperative/Non-Predictive	2.50	-1.71	-3.50	-14.14
Non-Cooperative/Predictive	-4.47	-7.08	-9.00	-10.00
Non-Cooperative/Non-Predictive	1.67	-2.89	-6.36	-10.63



# ATC Approval vs Upload Time

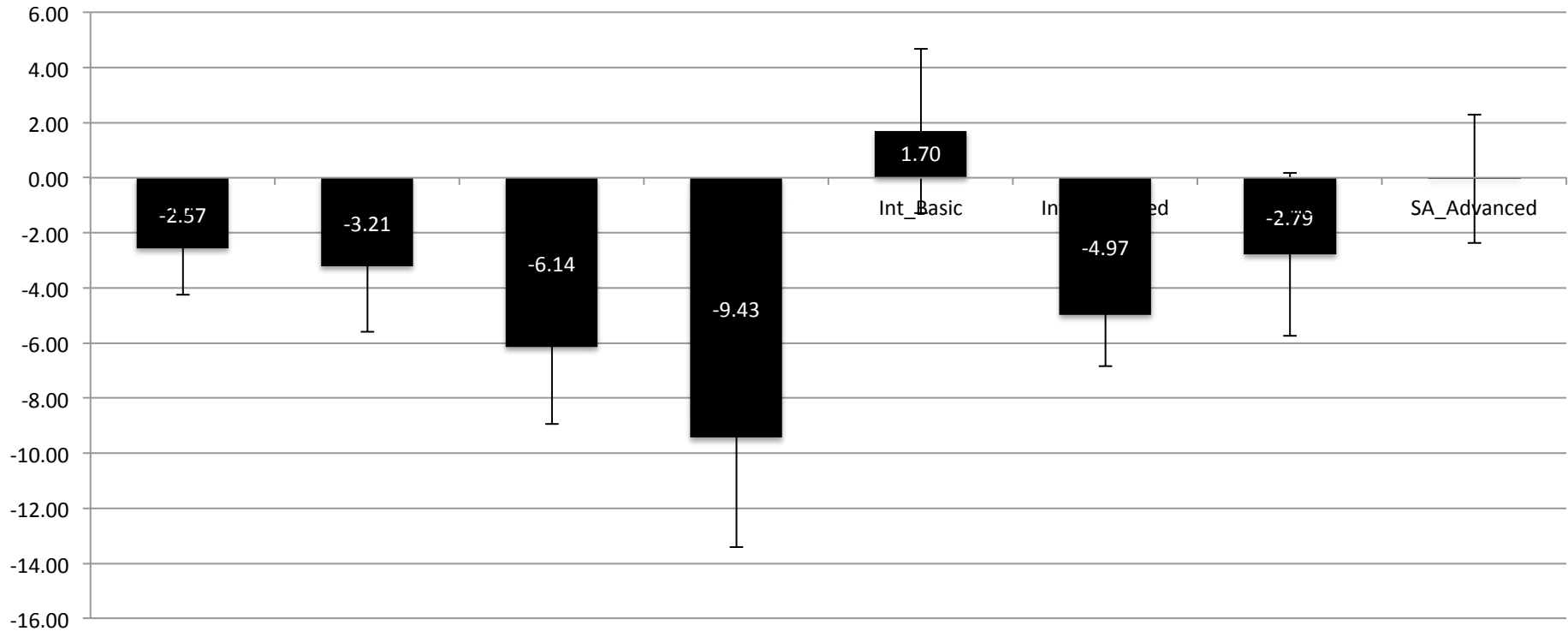




# ATC Approval vs Upload Time

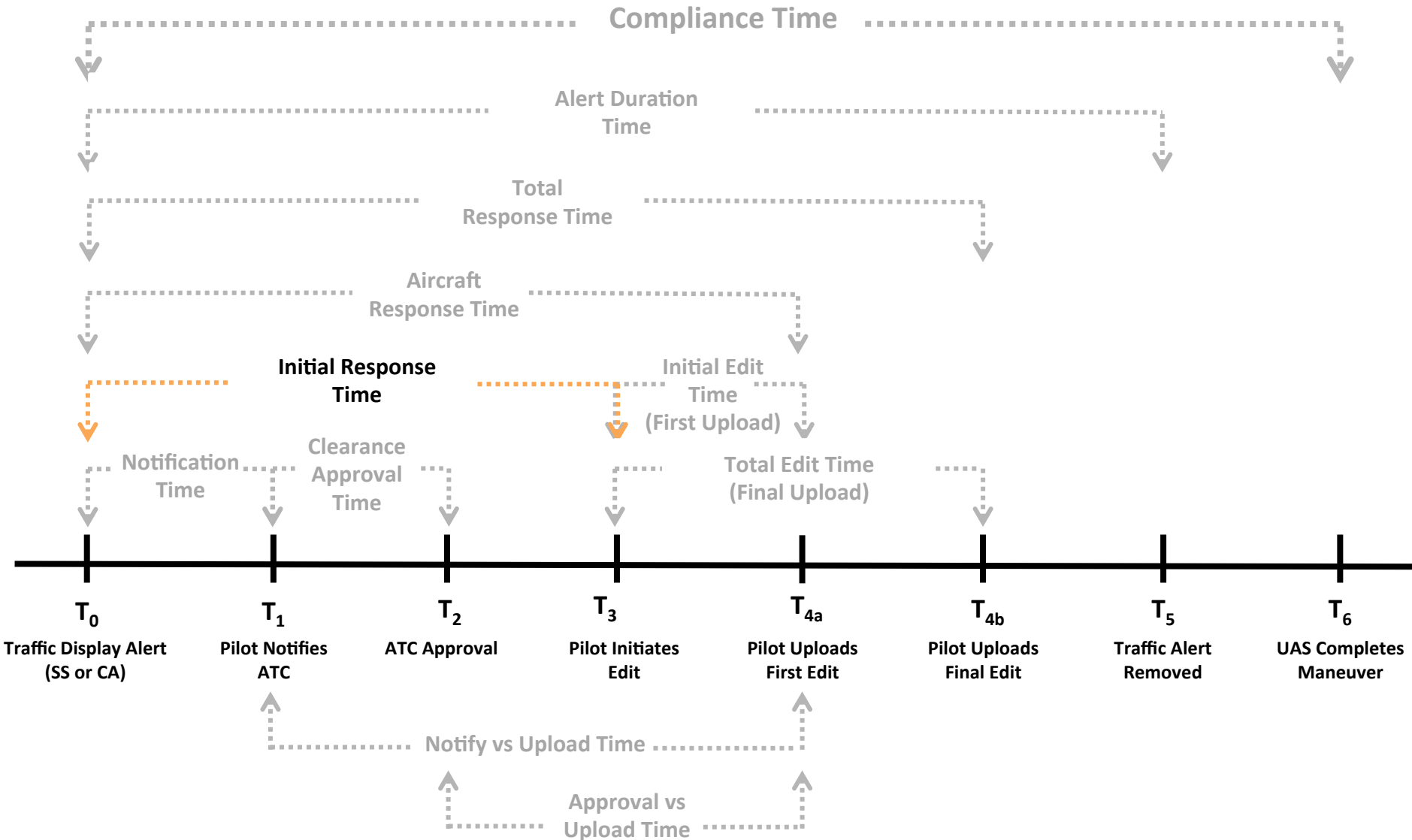


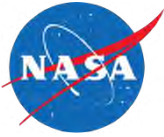
IHITL and PT4 Display Comparison



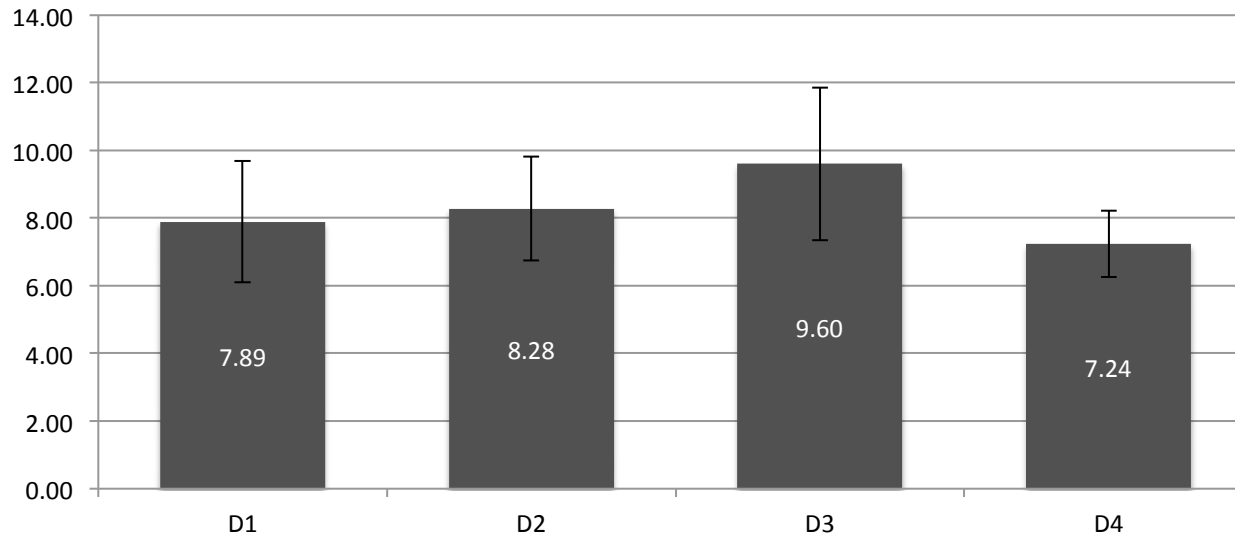


# Stages of Pilot DAA Task





# Initial Response Time



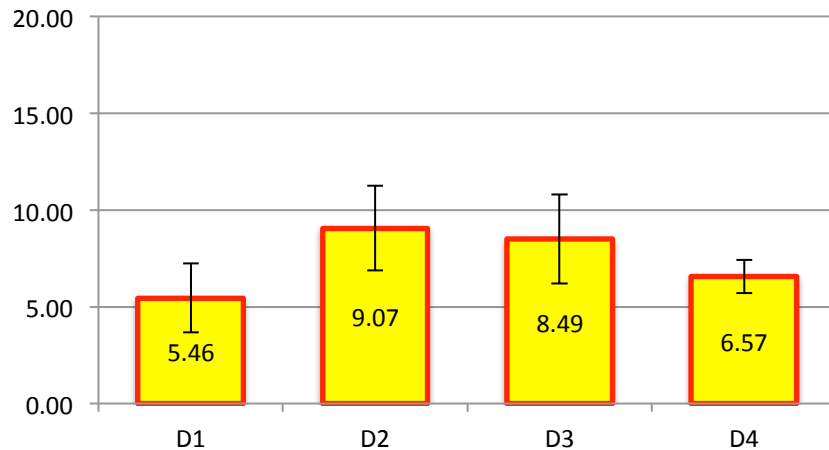
- There was no significant effect of Display on Initial Response Time for all SS alerts,  $p > .05$
- Pilots took an average of **8.25 seconds** to initiate an edit in response to a Predictive SS alert



# Initial Response Time

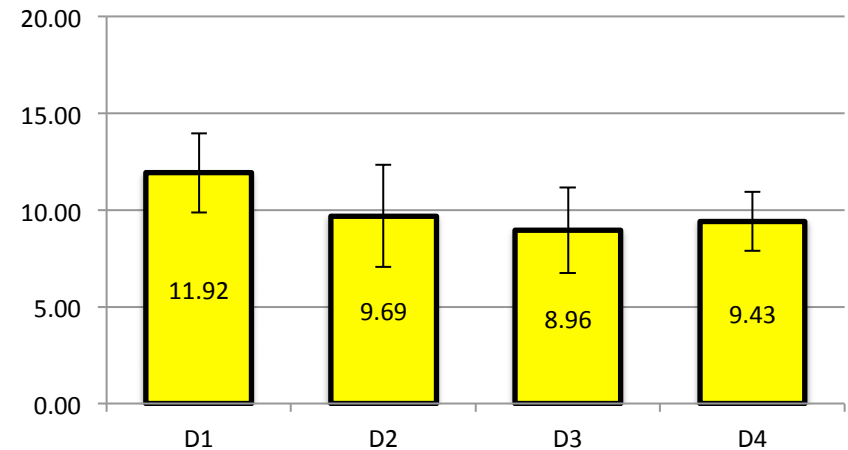


## Predictive SS Alerts



- There was no significant effect of Display on Initial Response Time for Predictive SS alerts,  $p > .05$
- Pilots took an average of **7.40 seconds** to initiate an edit in response to a Predictive SS alert

## Non-Predictive SS Alerts



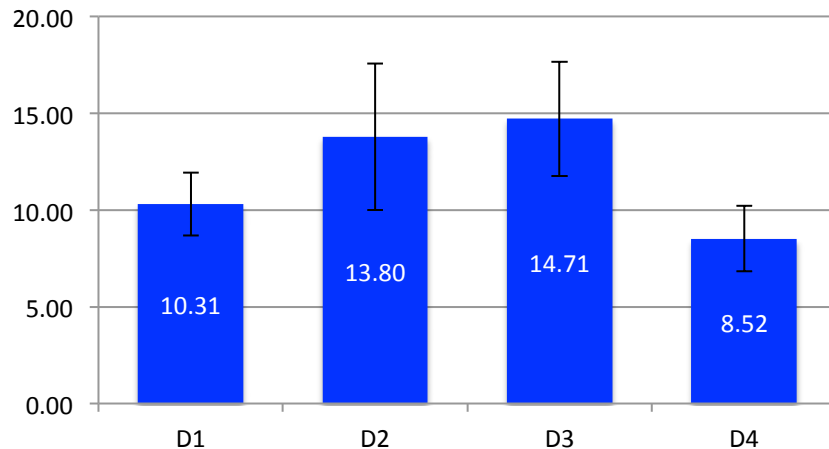
- There was no significant effect of Display on Initial Response Time for Non-Predictive SS alerts,  $p > .05$
- Pilots took an average of **10.00 seconds** to initiate an edit in response to a Non-Predictive SS alert



# Initial Response Time

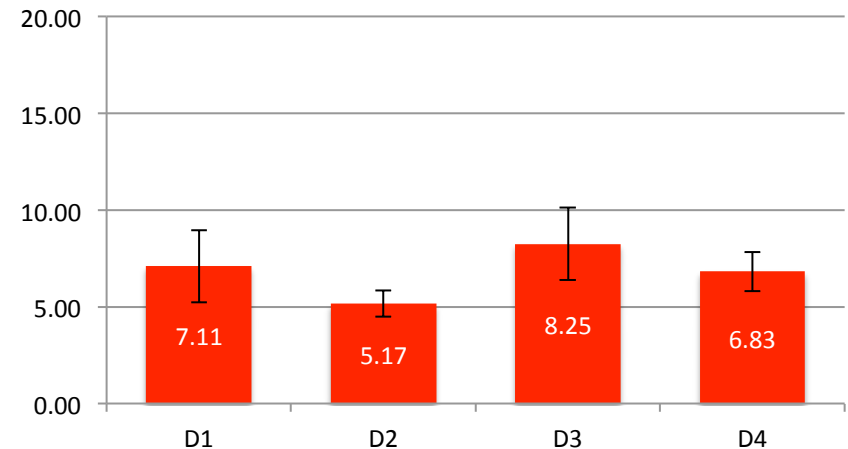


## Cooperative SS Alerts



- There was no significant effect of Display on Initial Response Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **11.84 seconds** to initiate an edit in response to a Cooperative SS alert

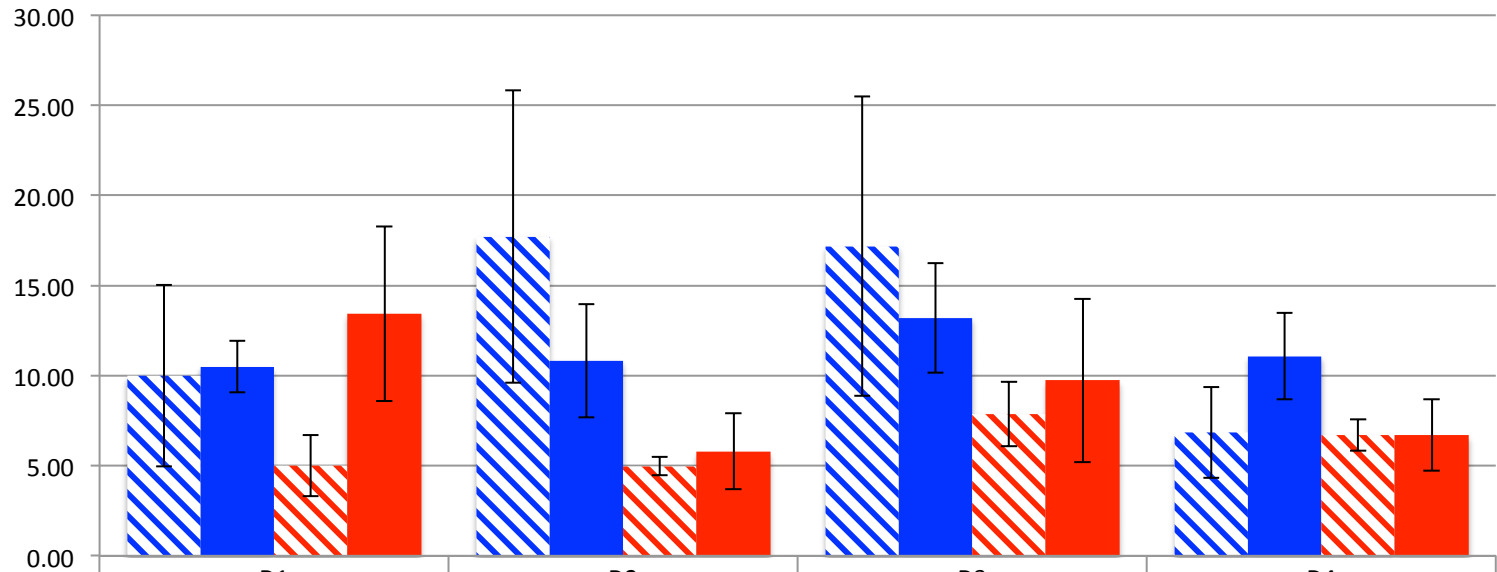
## Non-Cooperative SS Alerts



- There was no significant effect of Display on Initial Response Time for Non-Cooperative SS alerts,  $p > .05$
- Pilots took an average of **6.84 seconds** to initiate an edit in response to a Non-Cooperative SS alert



# Initial Response Time

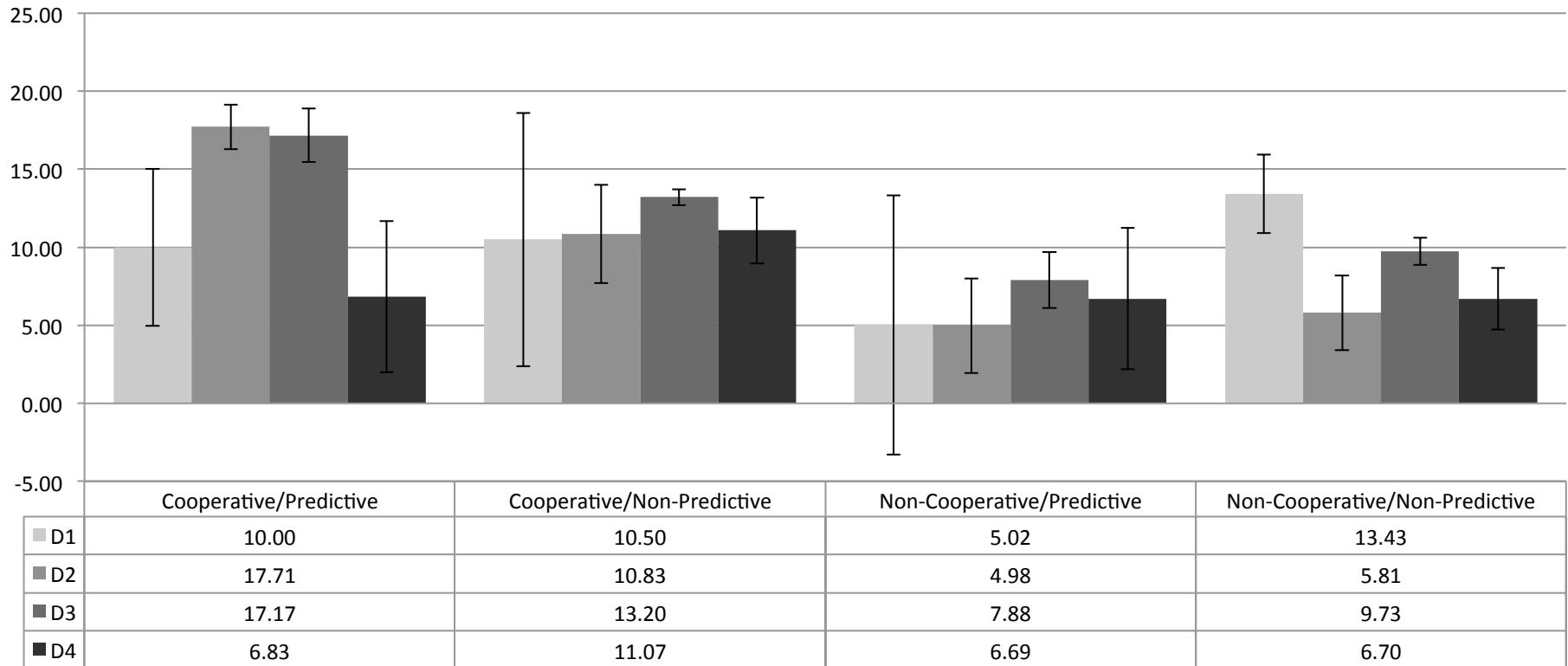


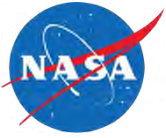
Cooperative/Predictive	D1	10.00	D2	17.71	D3	17.17	D4	6.83
Cooperative/Non-Predictive		10.50		10.83		13.20		11.07
Non-Cooperative/Predictive		5.02		4.98		7.88		6.69
Non-Cooperative/Non-Predictive		13.43		5.81		9.73		6.70





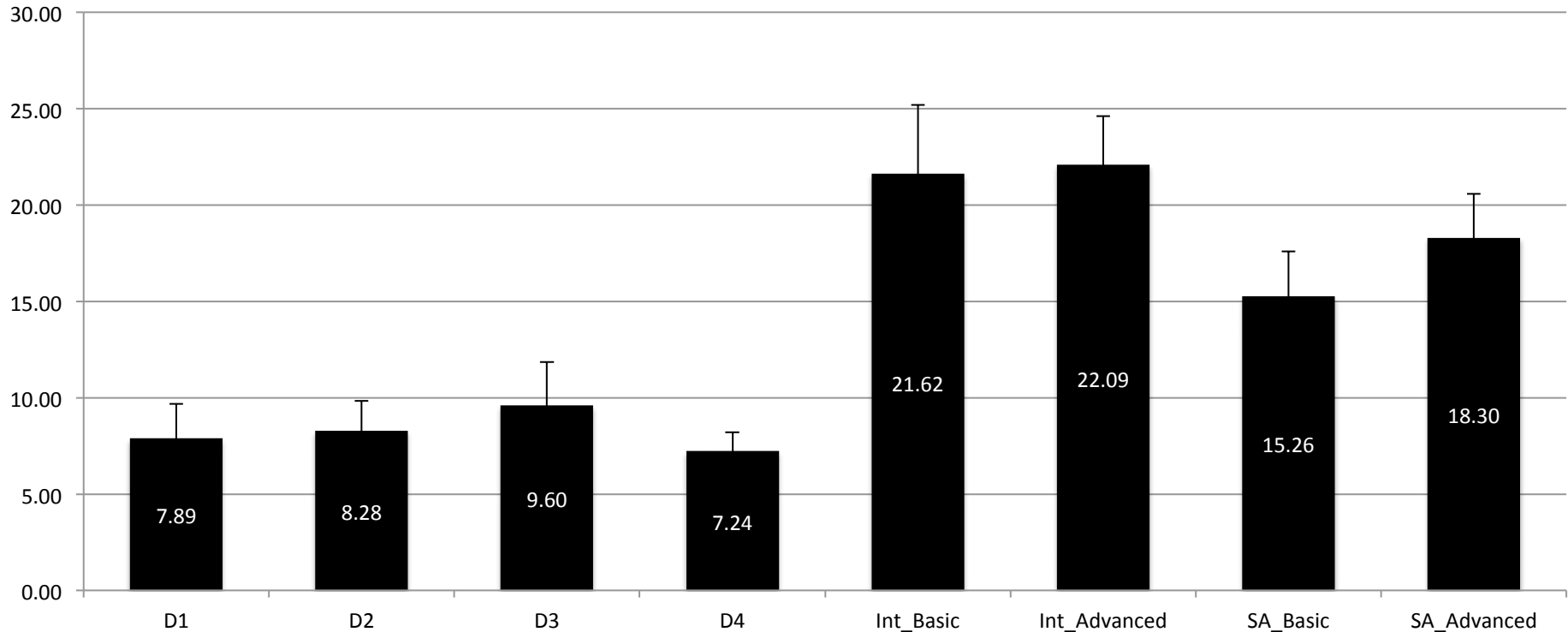
# Initial Response Time





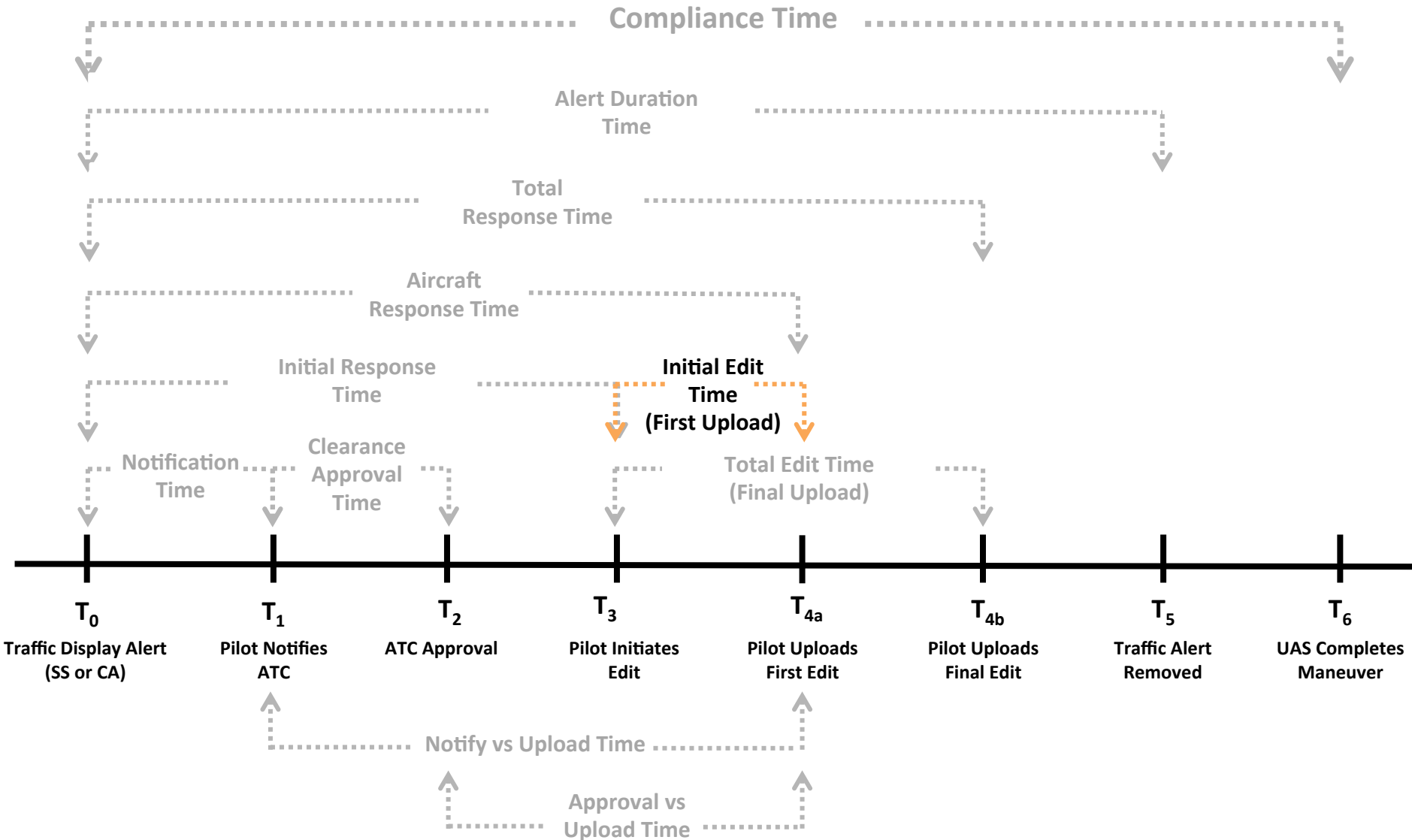
# Initial Response Time

IHITL and PT4 Display Comparison



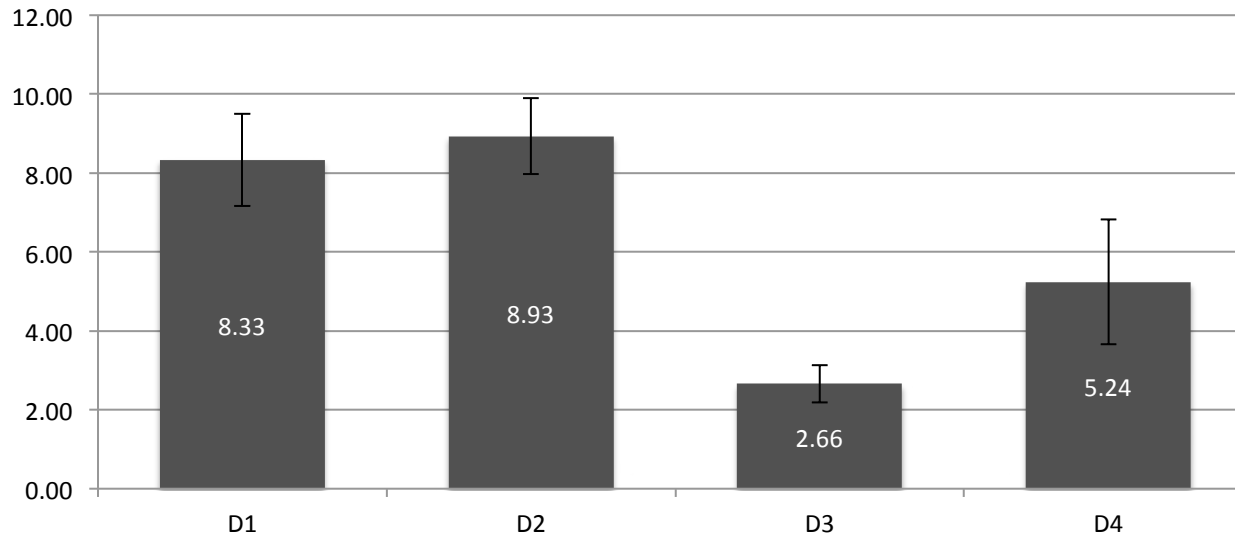


# Stages of Pilot DAA Task

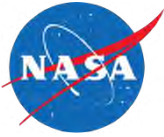




# Initial Edit Time



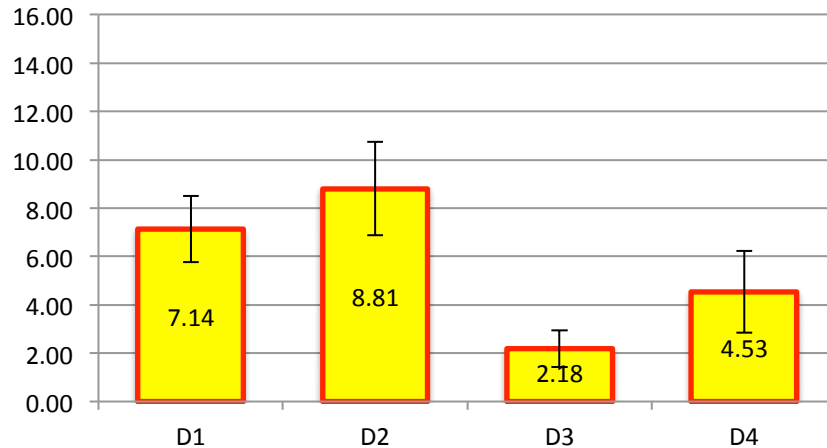
- There was a significant effect of Display on Initial Edit Time for all SS alerts,  $p < .01$ 
  - D3 was significantly faster than D1 and D2
- Pilots took an average of **6.29 seconds** to complete their first edit in response to SS alerts



# Initial Edit Time

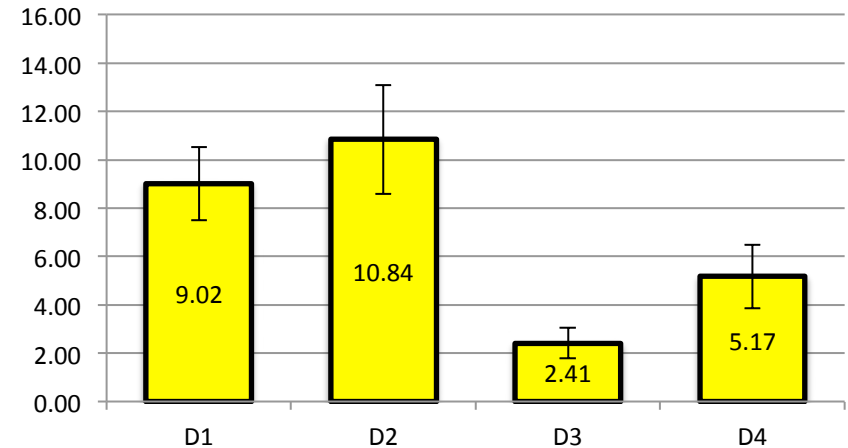


## Predictive SS Alerts



- There was a significant effect of Display on Initial Edit Time for Predictive SS alerts,  $p < .05$ 
  - D3 was significantly faster than D1
- Pilots took an average of **5.67 seconds** to complete their first edit in response to Predictive SS alerts

## Non-Predictive SS Alerts



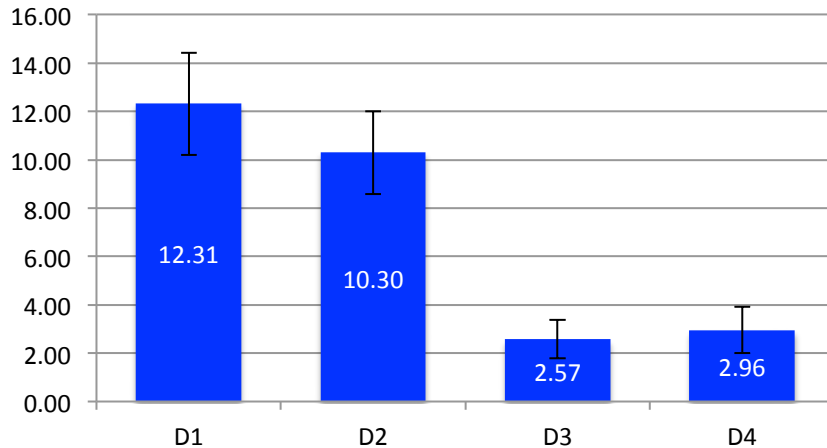
- There was a significant effect of Display on Initial Edit Time for Non-Predictive SS alerts,  $p < .05$ 
  - D3 was significantly faster than D1 and D2
- Pilots took an average of **6.86 seconds** to complete their first edit in response to Non-Predictive SS alert



# Initial Edit Time

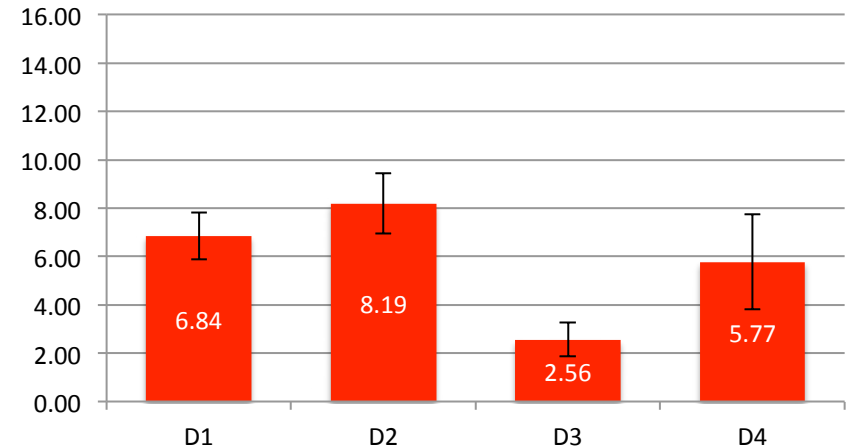


## Cooperative SS Alerts



- There was a significant effect of Display on Initial Edit Time for Cooperative SS alerts,  $p < .01$ 
  - D3 and D4 were both significantly faster than D1 and D2
  - No difference between D1 and D2
  - No difference between D3 and D4
- Pilots took an average of **7.04 seconds** to complete their first edit in response to Cooperative SS alerts

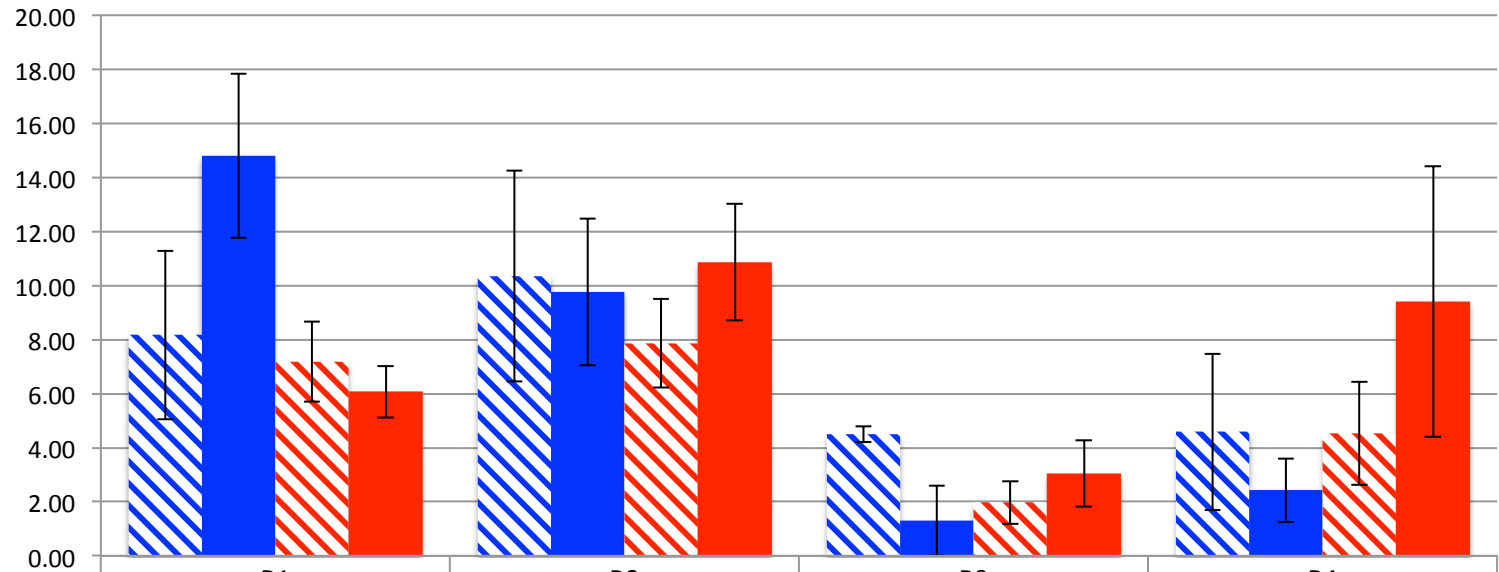
## Non-Cooperative SS Alerts



- There was a near significant effect of Display on Initial Edit Time for Non-Cooperative Alerts,  $p = .056$
- Pilots took an average of **5.84 seconds** to complete their first edit in response to Non-Cooperative alerts



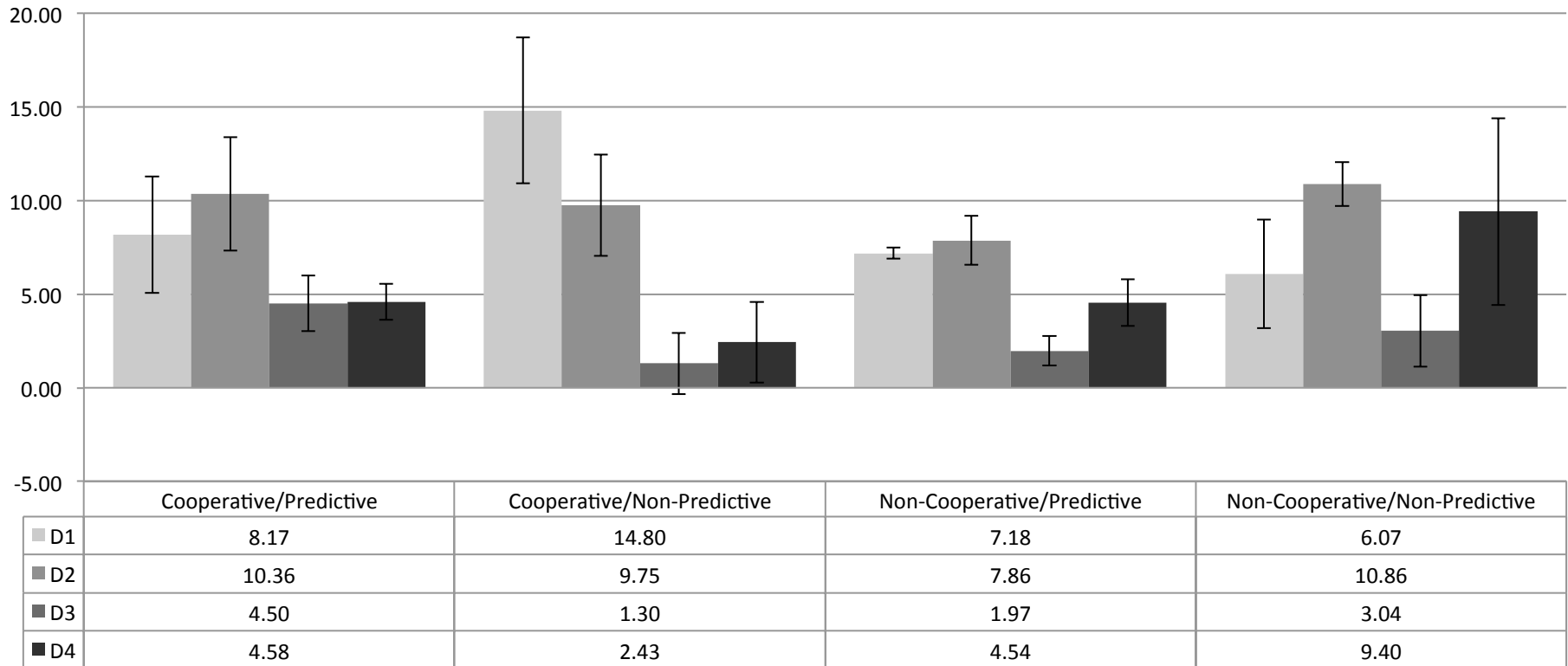
# Initial Edit Time



	D1	D2	D3	D4
Cooperative/Predictive	8.17	10.36	4.50	4.58
Cooperative/Non-Predictive	14.80	9.75	1.30	2.43
Non-Cooperative/Predictive	7.18	7.86	1.97	4.54
Non-Cooperative/Non-Predictive	6.07	10.86	3.04	9.40



# Initial Edit Time

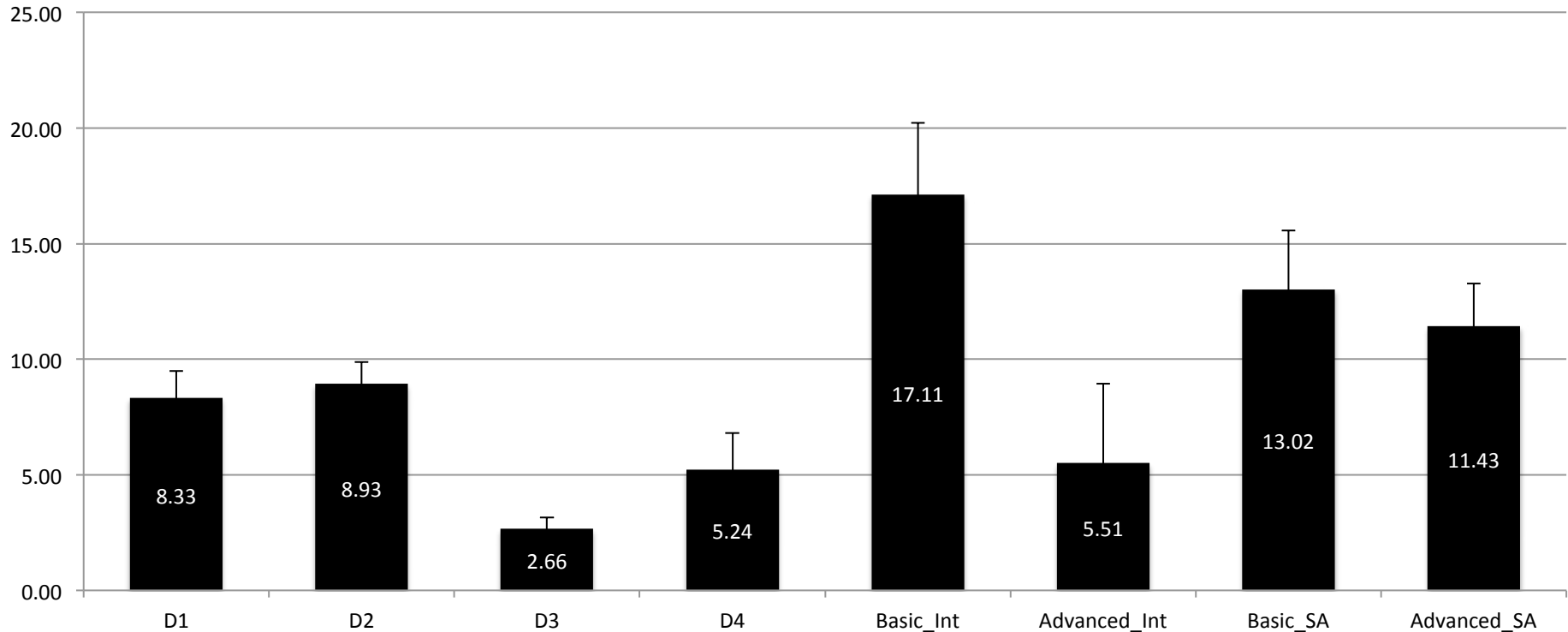






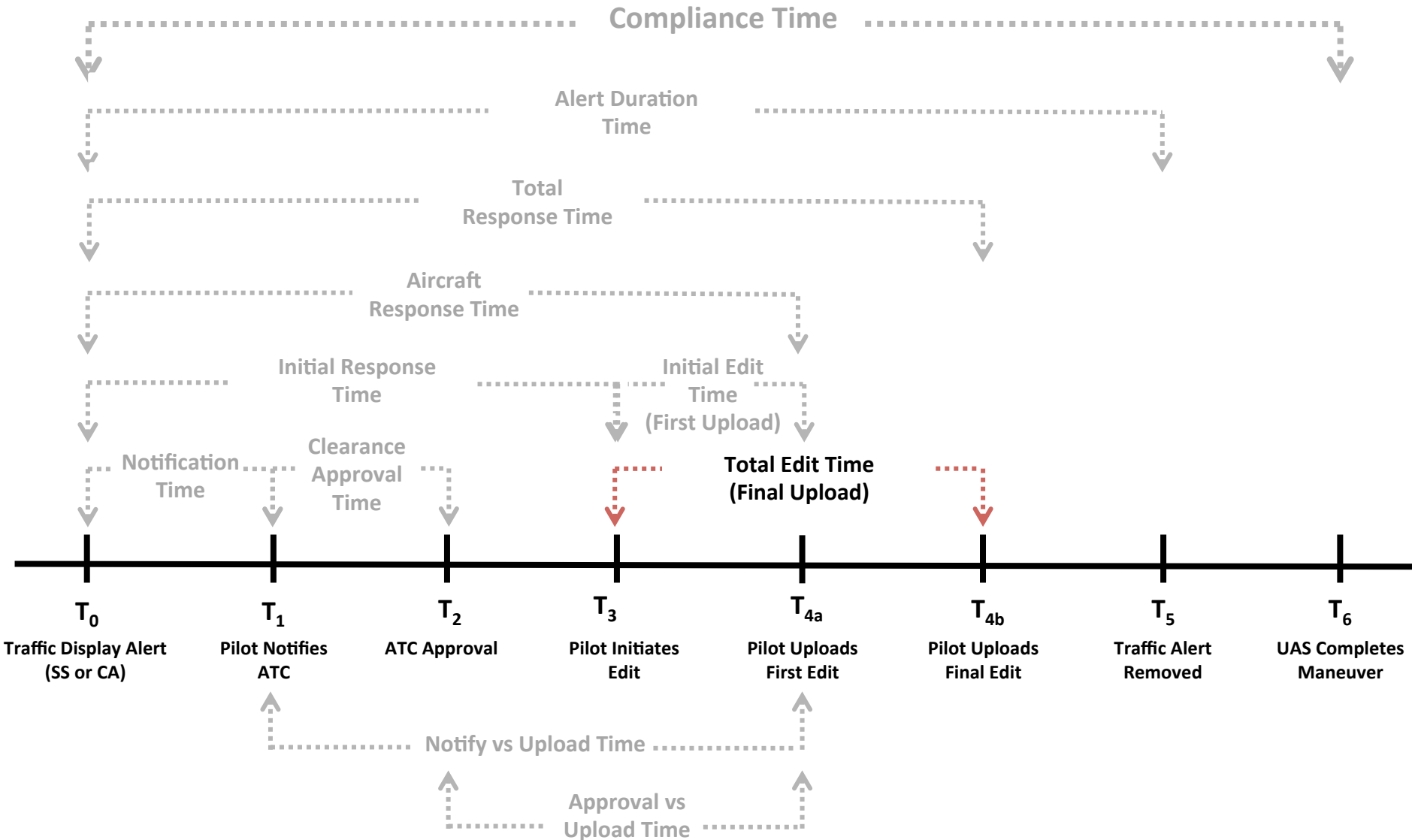
# Initial Edit Time

## IHITL and PT4 Display Comparison



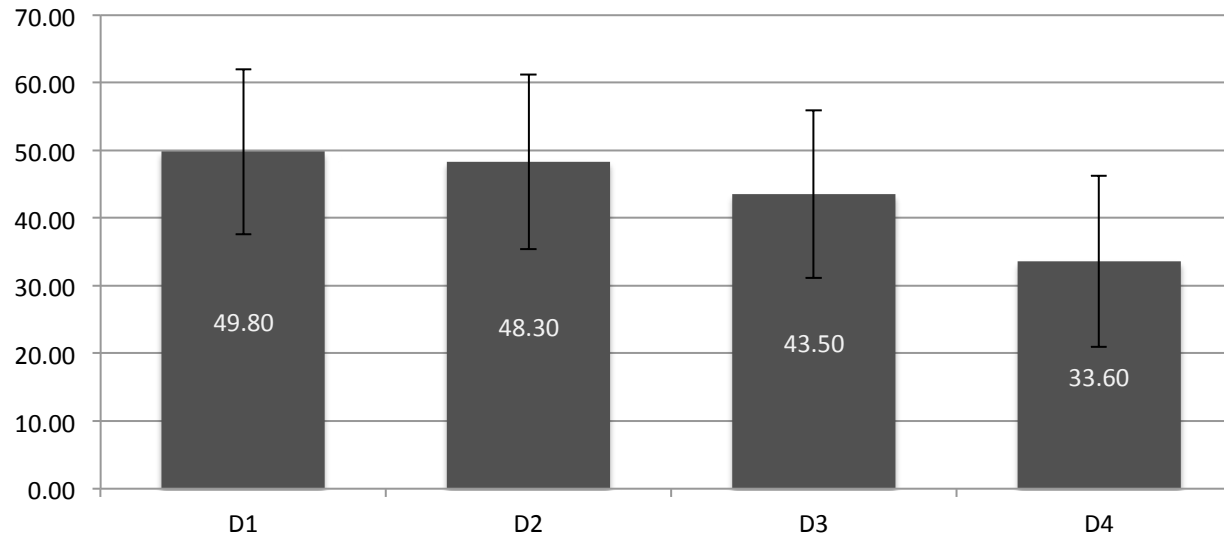


# Stages of Pilot DAA Task





# Total Edit Time

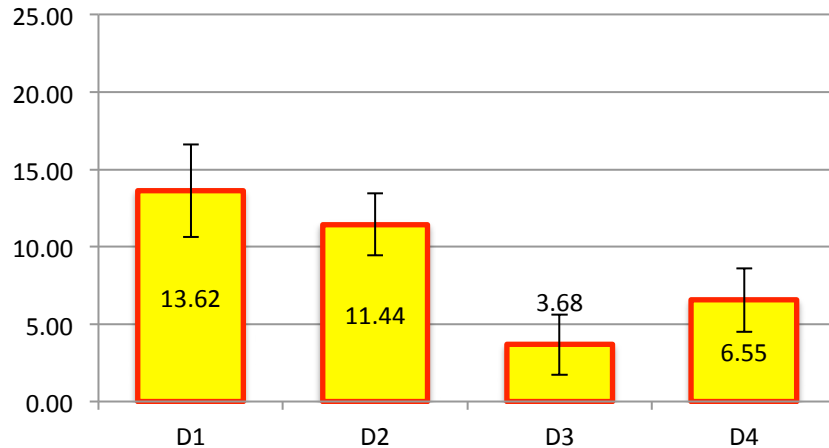


- There was a not significant effect of Display on Total Edit Time for all SS alerts,  $p > .05$
- Pilots took an average of **9.83 seconds** to complete their final edit in response to SS alerts



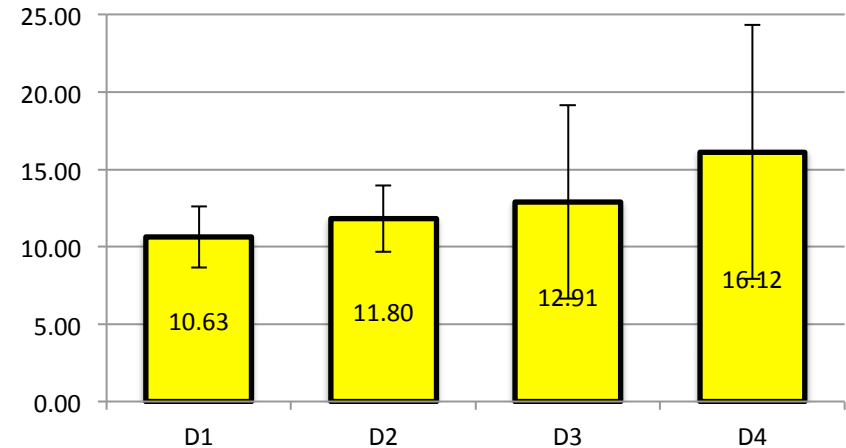
# Total Edit Time

## Predictive SS Alerts



- There was a significant effect of Display on Total Edit Time for Predictive alerts,  $p < .05$ 
  - D3 was significantly faster than D2, but no different than the other two displays
- Pilots took an average of **8.83 seconds** to complete their final edit in response to Predictive SS alerts

## Non-Predictive SS Alerts

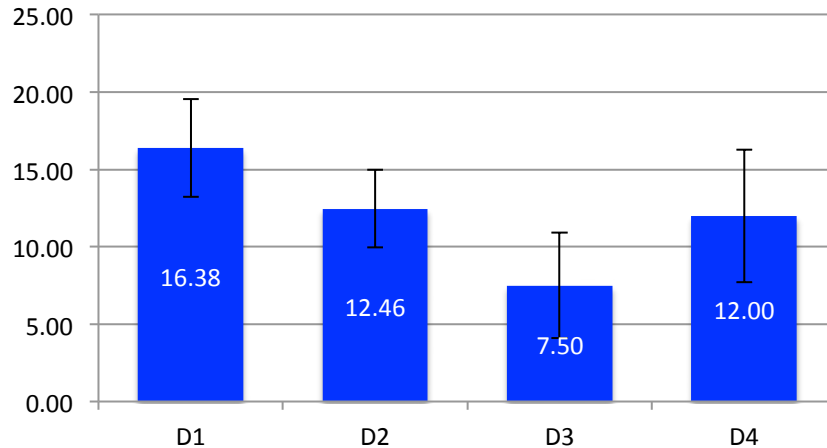


- There was no significant main effect of Display on Total Edit Time for Non-Predictive alerts,  $p > .05$
- Pilots took an average of **12.862 seconds** to complete their final edit in response to Non-Predictive SS alerts



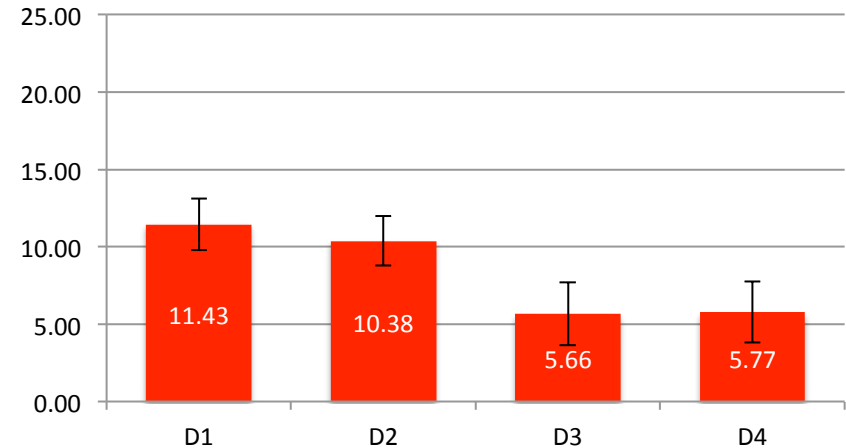
# Total Edit Time

## Cooperative SS Alerts



- There was no significant effect of Display on Total Edit Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **12.08 seconds** to complete their final edit in response to Cooperative SS alerts

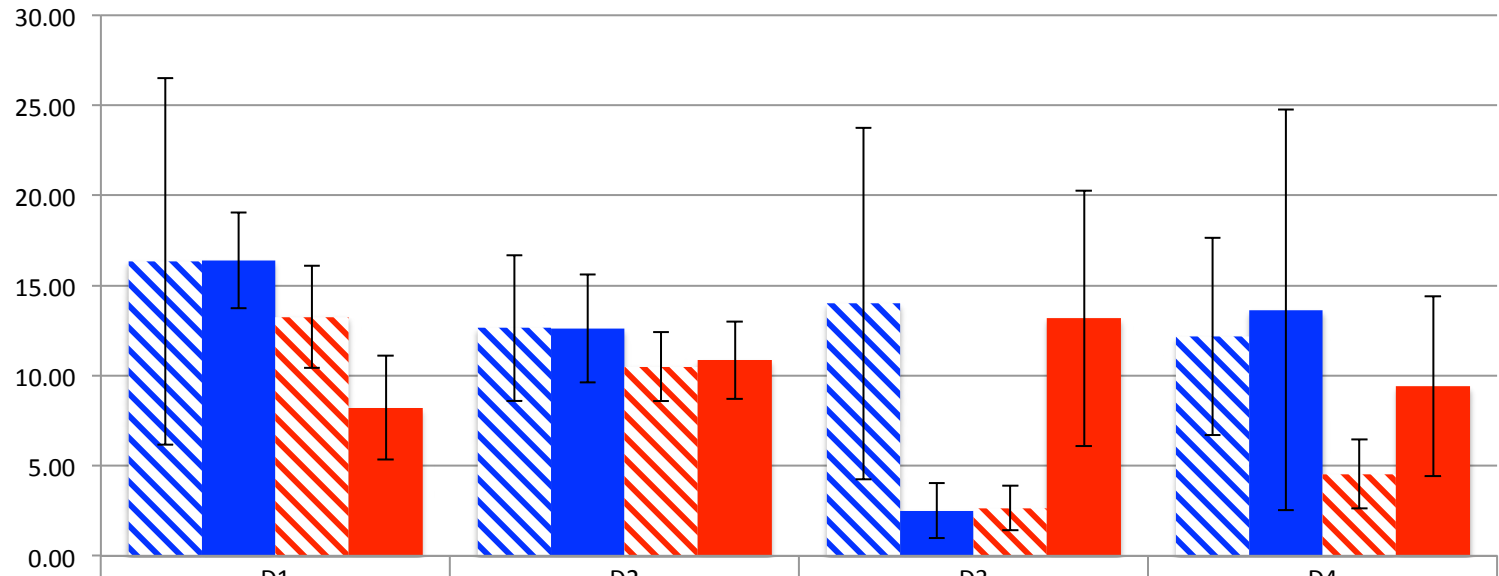
## Non-Cooperative SS Alerts



- There was a near significant effect of Display on Total Edit Time for Non-Cooperative SS alerts,  $p = .064$
- Pilots took an average of **8.31 seconds** to complete their final edit in response to Non-Cooperative alerts



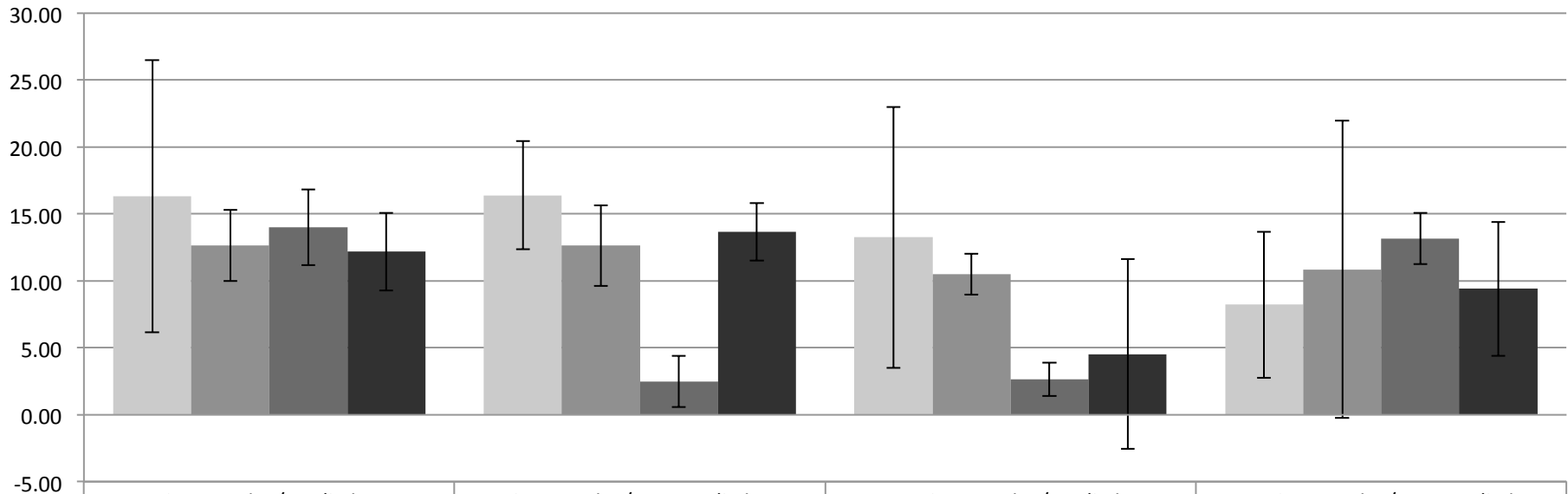
# Total Edit Time



Cooperative/Predictive	D1	16.33	D2	12.64	D3	14.00	D4	12.17
Cooperative/Non-Predictive	D1	16.40	D2	12.63	D3	2.50	D4	13.64
Non-Cooperative/Predictive	D1	13.26	D2	10.50	D3	2.64	D4	4.54
Non-Cooperative/Non-Predictive	D1	8.21	D2	10.86	D3	13.17	D4	9.40



# Total Edit Time

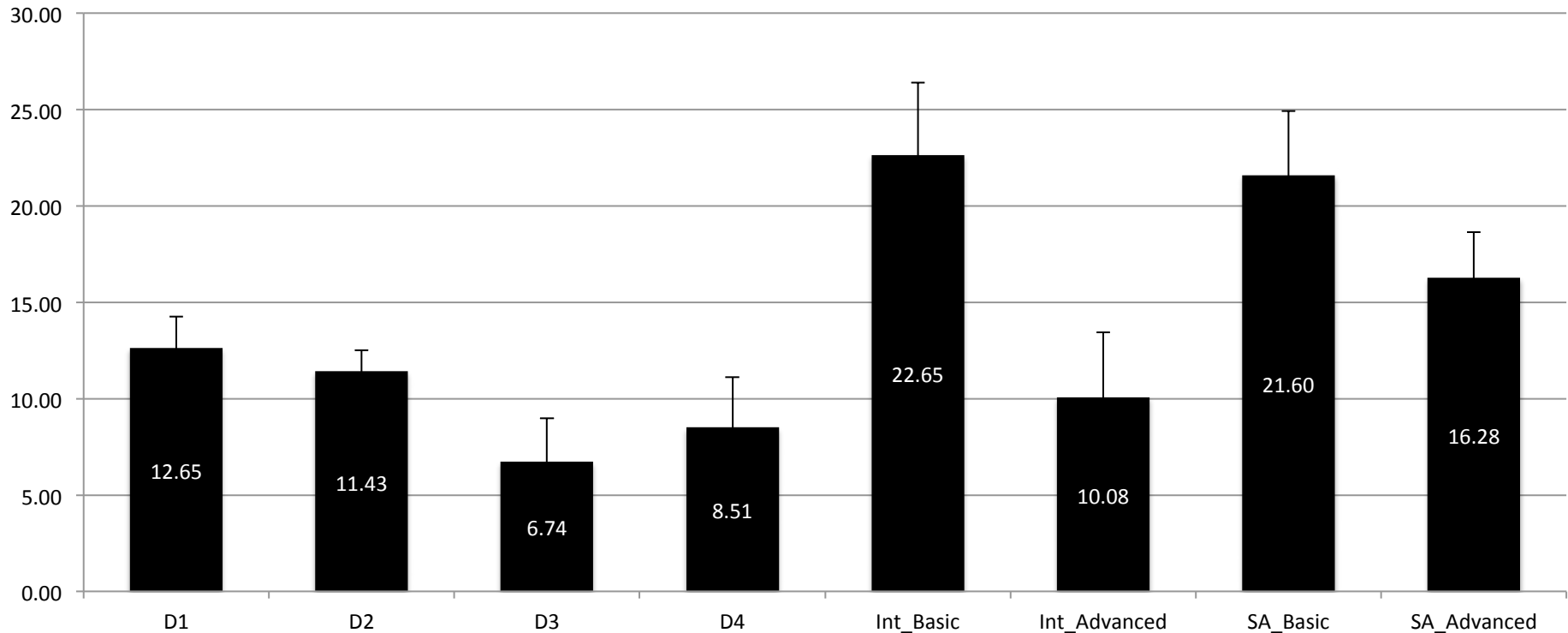


	Cooperative/Predictive	Cooperative/Non-Predictive	Non-Cooperative/Predictive	Non-Cooperative/Non-Predictive
D1	16.33	16.40	13.26	8.21
D2	12.64	12.63	10.50	10.86
D3	14.00	2.50	2.64	13.17
D4	12.17	13.64	4.54	9.40



# Total Edit Time

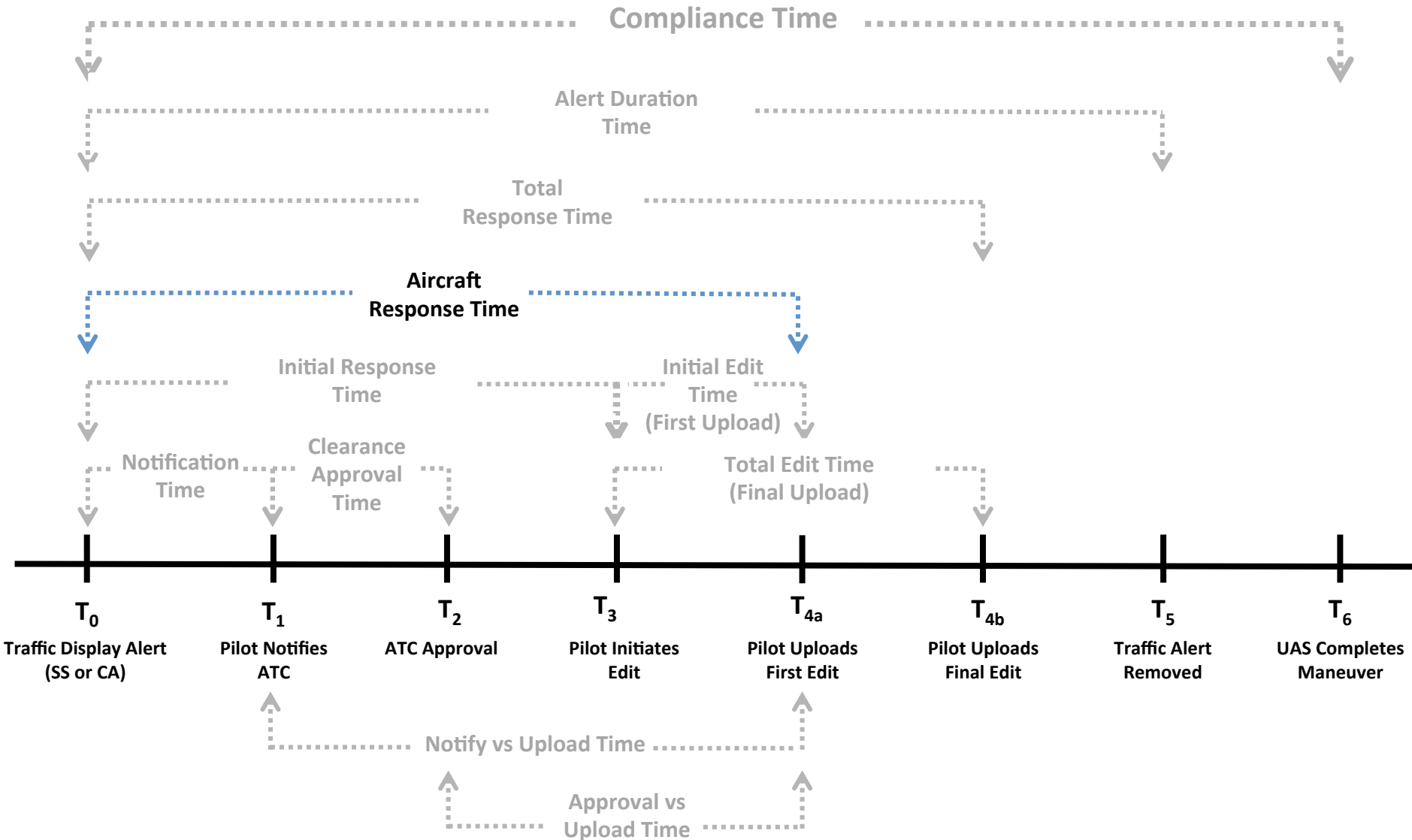
## IHITL and PT4 Display Comparison





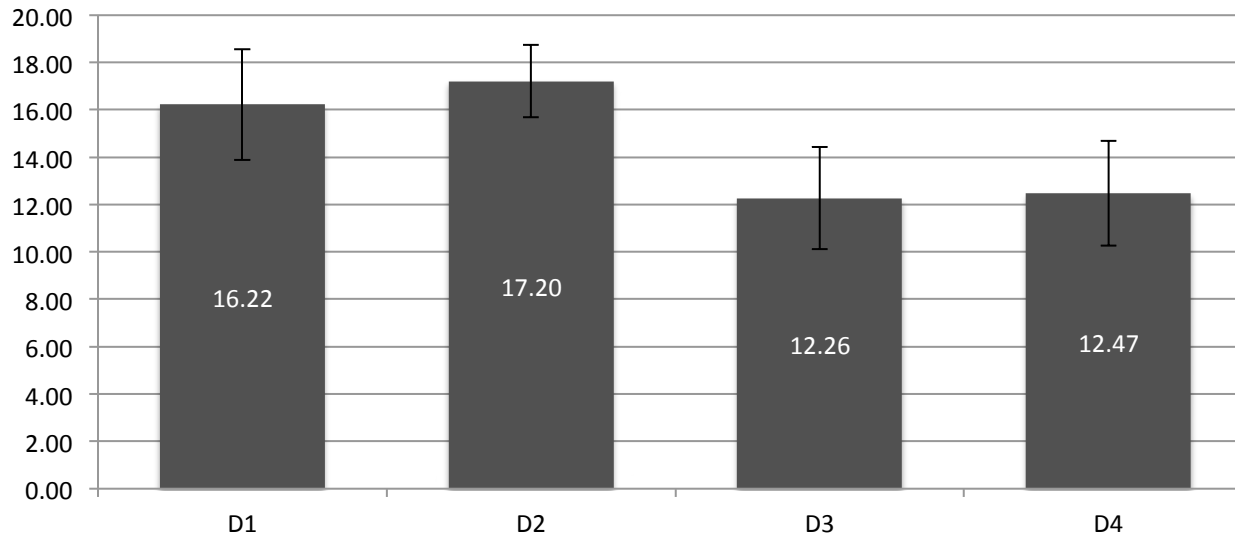


# Stages of Pilot DAA Task





# Aircraft Response Time



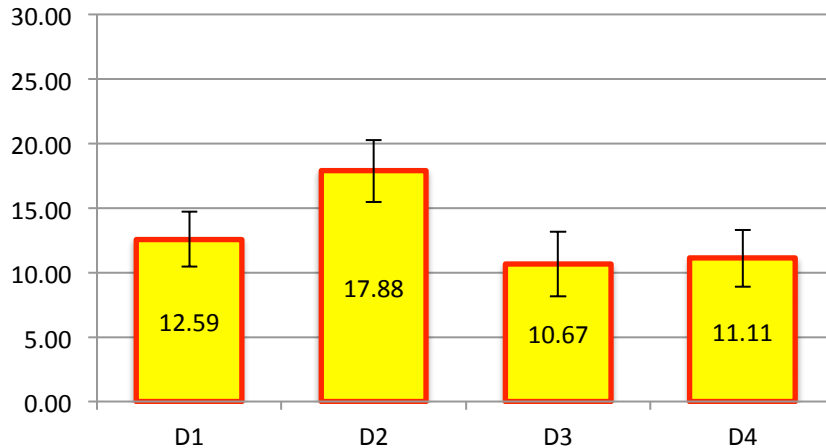
- There was a near significant effect of Display on Aircraft Response Time for all SS alerts,  $p = .069$
- Pilots took an average of **14.54 seconds** to upload their first maneuver in response to SS alerts (from first alert appearance)



# Aircraft Response Time

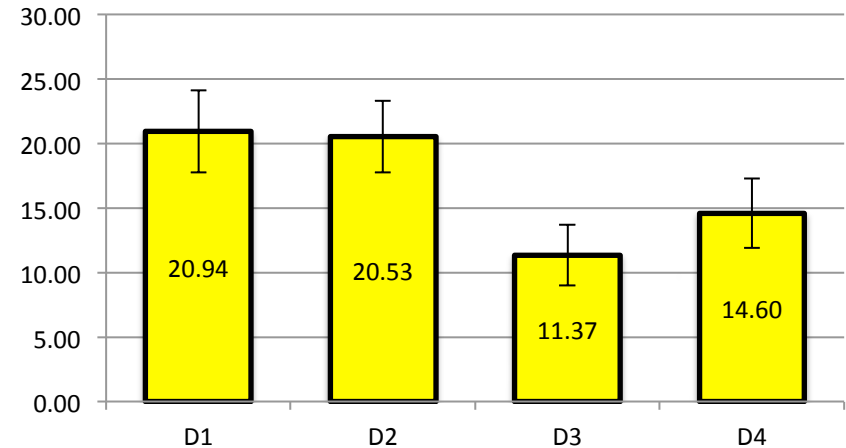


## Predictive SS Alerts



- There was a near significant effect of Display on Aircraft Response Time for Predictive SS alerts,  $p = .059$
- Pilots took an average of **13.06 seconds** to upload their first maneuver in response to Predictive SS alerts (from first alert appearance)

## Non-Predictive SS Alerts



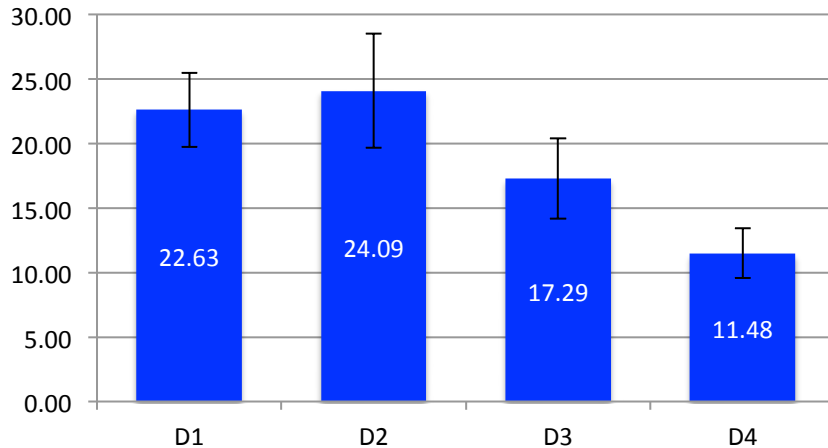
- There was a significant effect of Display on Aircraft Response Time for Non-Predictive SS alerts,  $p < .05$ 
  - No differences between displays were significant
- Pilots took an average of **16.86 seconds** to upload their first maneuver in response to Non-Predictive SS alerts (from first alert appearance)



# Aircraft Response Time

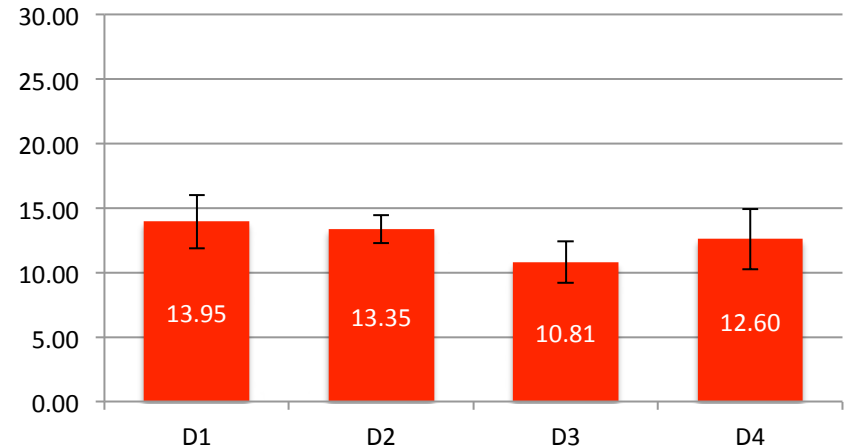


## Cooperative SS Alerts

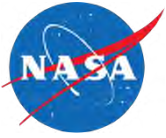


- There was a significant effect of Display on Aircraft Response Time for Cooperative SS alerts,  $p < .01$ 
  - D4 was significantly faster than D1 and D2
- Pilots took an average of **18.87 seconds** to upload their first maneuver in response to Cooperative SS alerts (from first alert appearance)

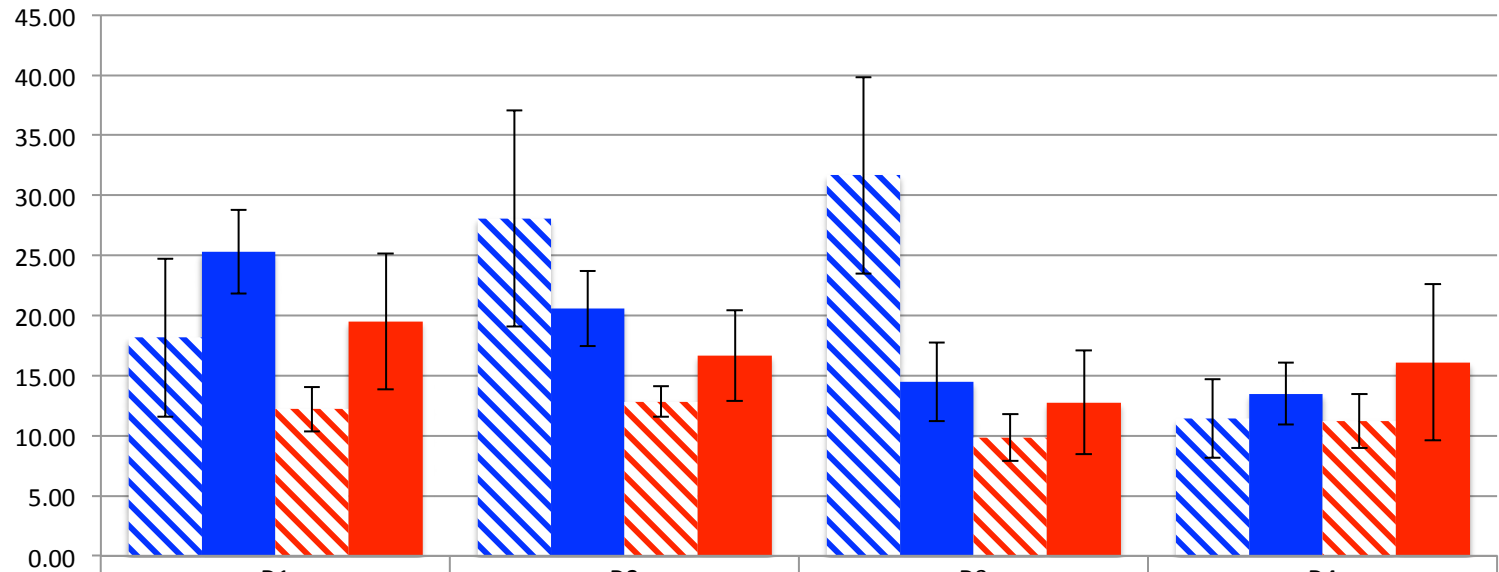
## Non-Cooperative SS Alerts



- There was no significant effect of Display on Aircraft Response Time for Non-Cooperative SS alerts,  $p > .05$
- Pilots took an average of **12.68 seconds** to upload their first maneuver in response to Non-Cooperative SS alerts (from first alert appearance)



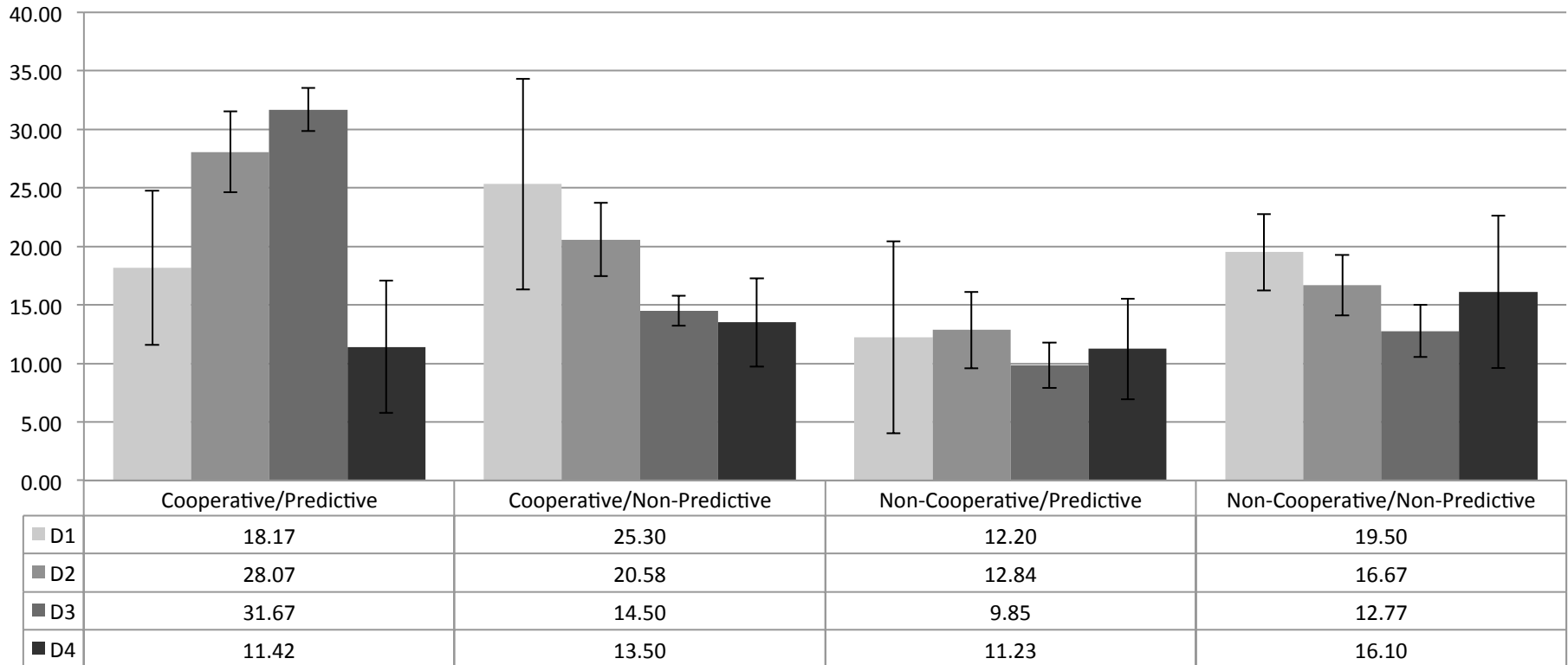
# Aircraft Response Time



Cooperative/Predictive	D1	18.17	D2	28.07	D3	31.67	D4	11.42
Cooperative/Non-Predictive	D1	25.30	D2	20.58	D3	14.50	D4	13.50
Non-Cooperative/Predictive	D1	12.20	D2	12.84	D3	9.85	D4	11.23
Non-Cooperative/Non-Predictive	D1	19.50	D2	16.67	D3	12.77	D4	16.10



# Aircraft Response Time

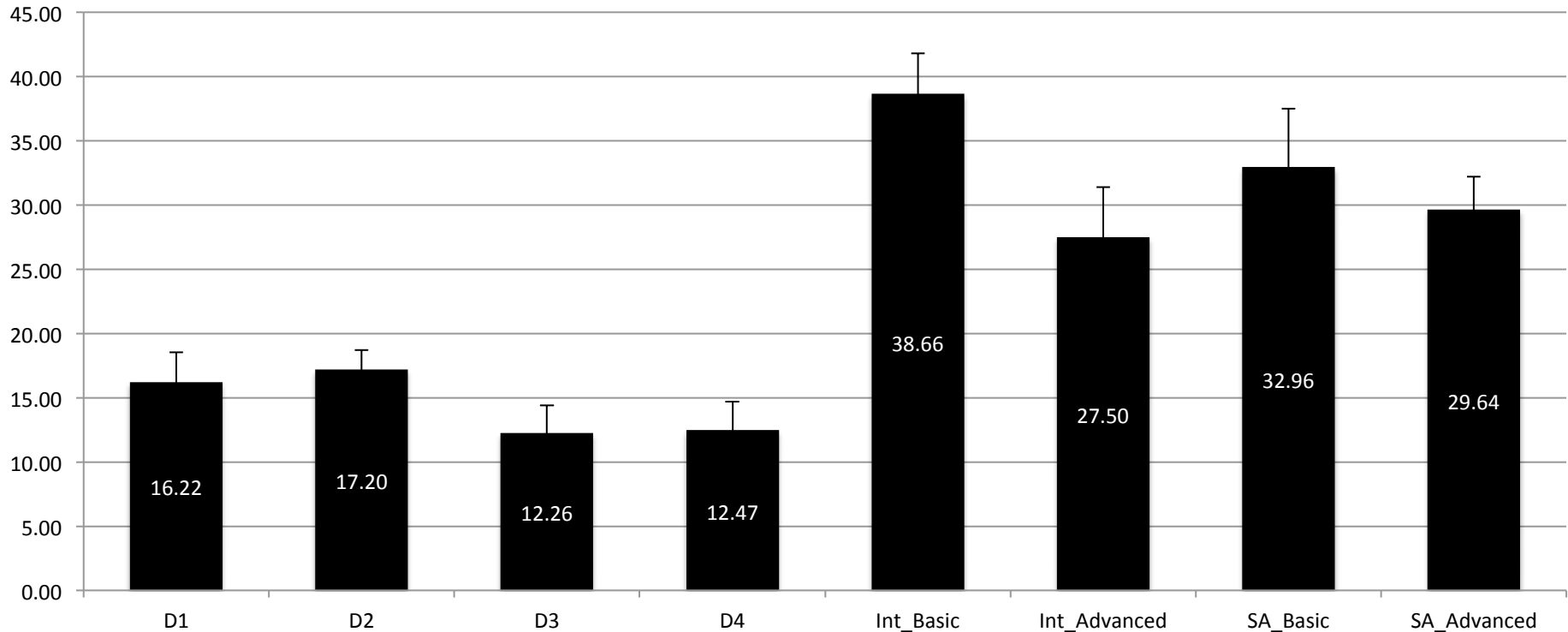


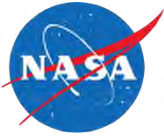


# Aircraft Response Time

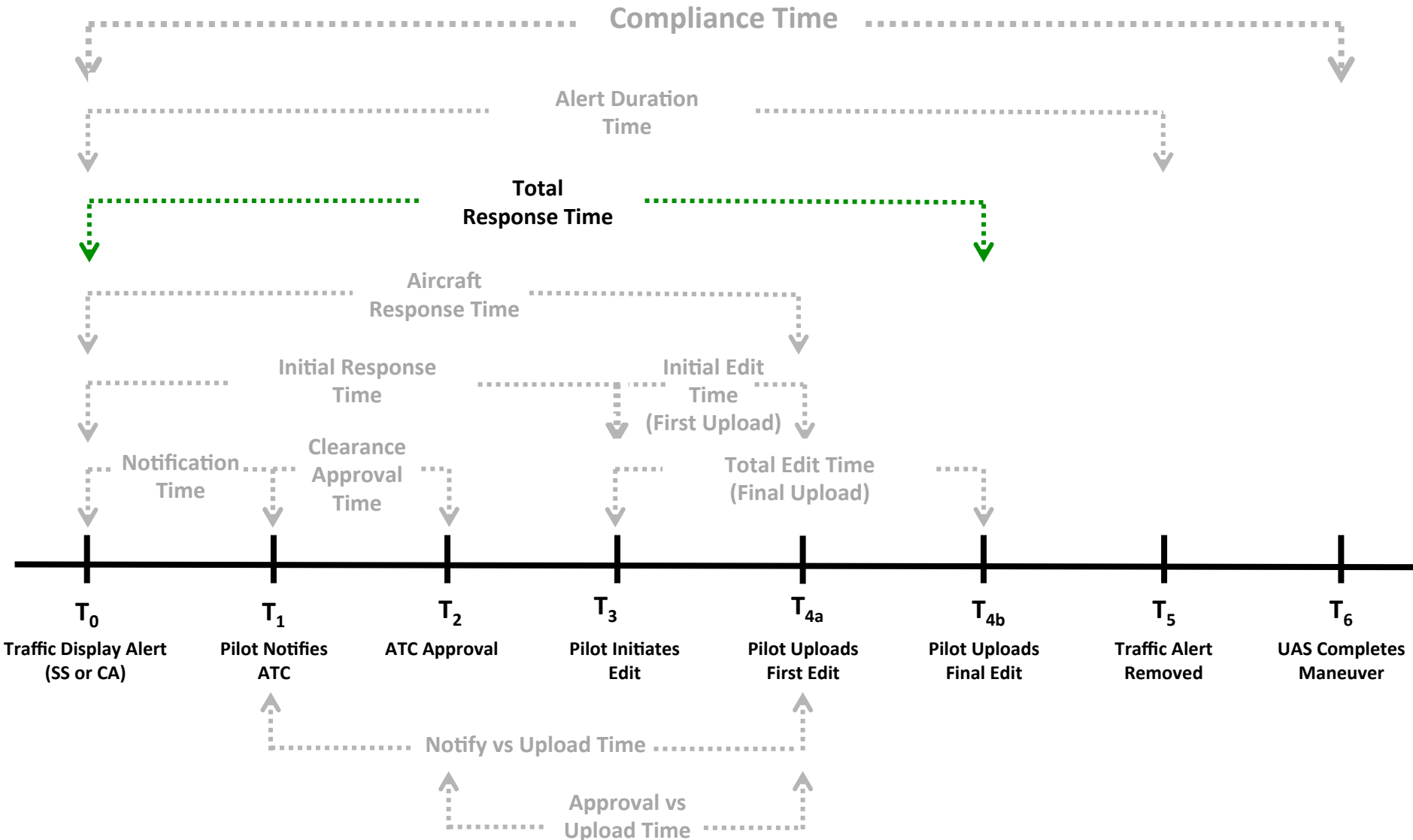


IHITL and PT4 Display Comparison





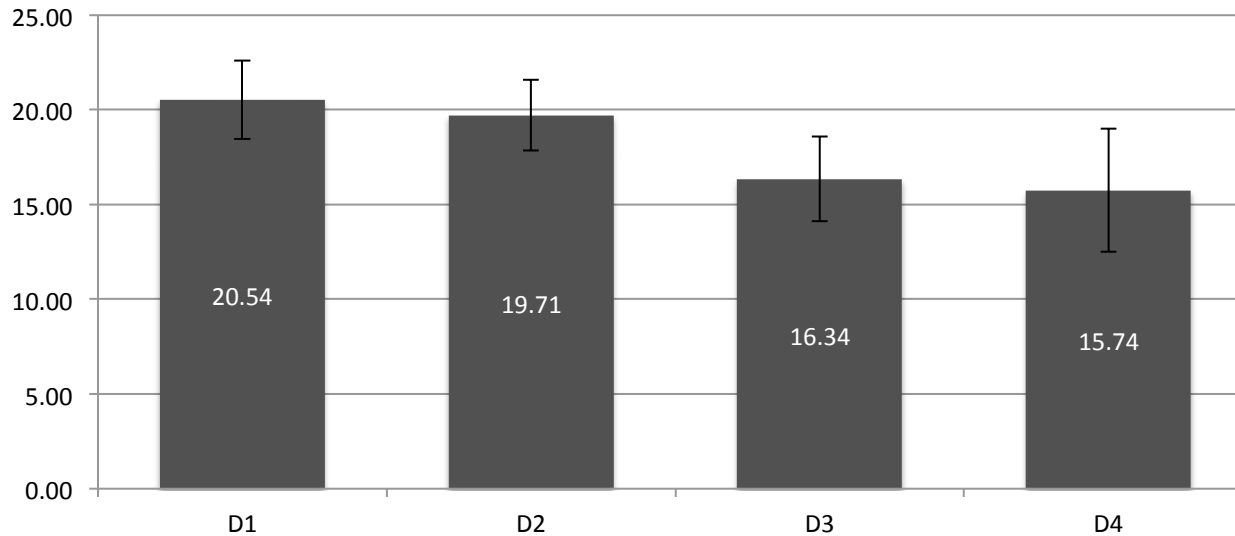
# Stages of Pilot DAA Task







# Total Response Time



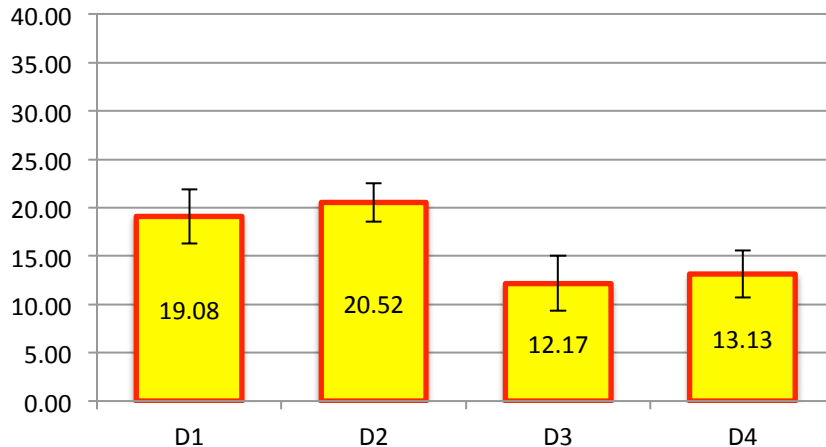
- There was not a significant effect of Information on Total Response Time for all SS alerts,  $p > .05$
- Pilots took an average of **18.08 seconds** to complete their final edit in response to SS alerts (from first alert appearance)



# Total Response Time

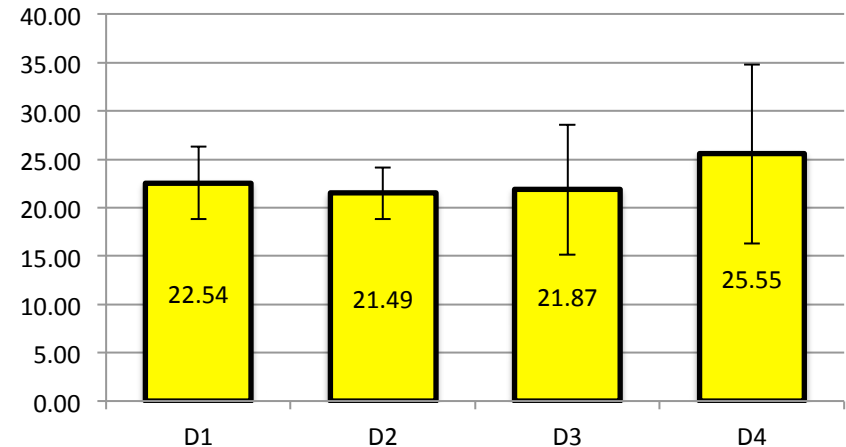


## Predictive SS Alerts



- There was a near significant effect of Display on Total Response Time for Predictive SS alerts,  $p = .056$
- Pilots took an average of **16.22 seconds** to complete their final edit in response to Predictive SS alerts (from first alert appearance)

## Non-Predictive SS Alerts



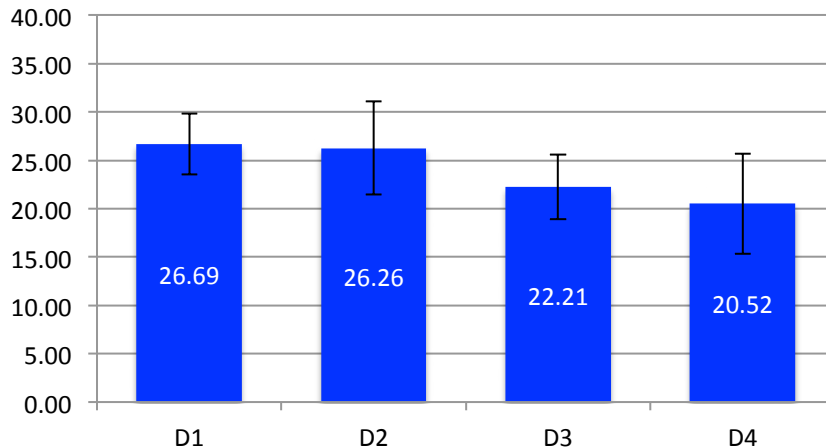
- There was no significant effect of Display on Total Response Time,  $p > .05$
- Pilots took an average of **22.86 seconds** to complete their final edit in response to Non-Predictive SS alerts (from first alert appearance)



# Total Response Time

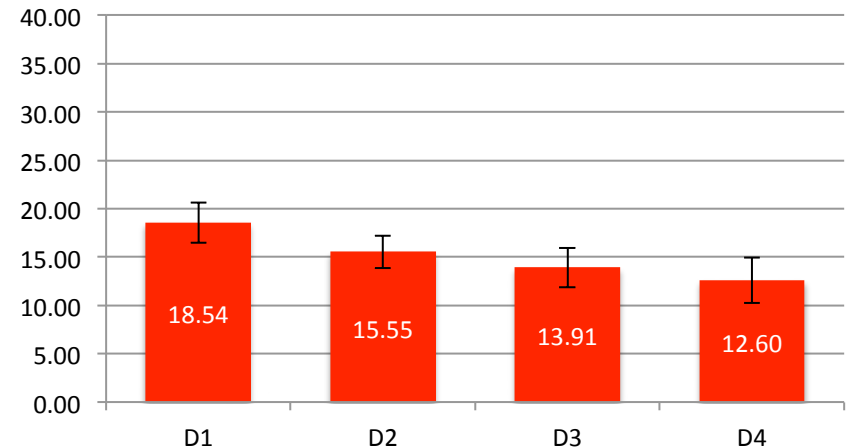


## Cooperative SS Alerts



- There was no significant effect of Information on Aircraft Response Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **23.92 seconds** to complete their final edit in response to Cooperative SS alerts (from first alert appearance)

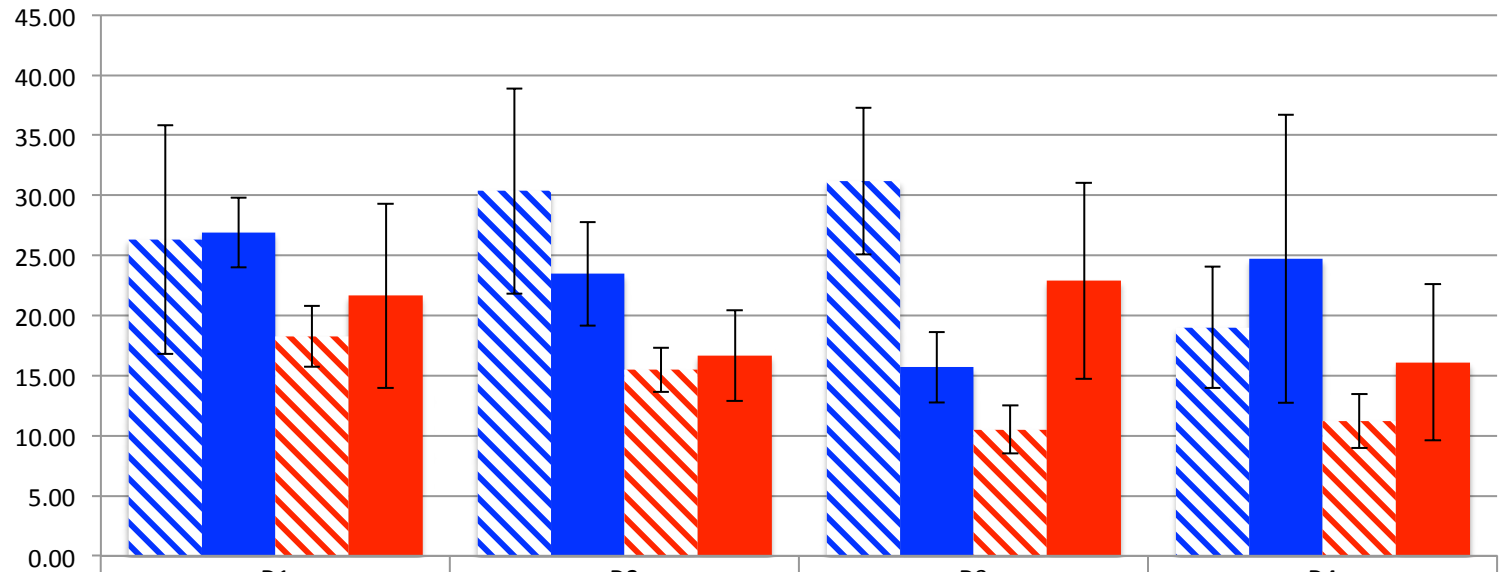
## Non-Cooperative SS Alerts



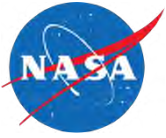
- There was no significant effect of Display on Aircraft Response Time for Non-Cooperative SS alerts,  $p > .05$
- Pilots took an average of **15.15 seconds** to complete their final edit in response to Non-Cooperative SS alerts (from first alert appearance)



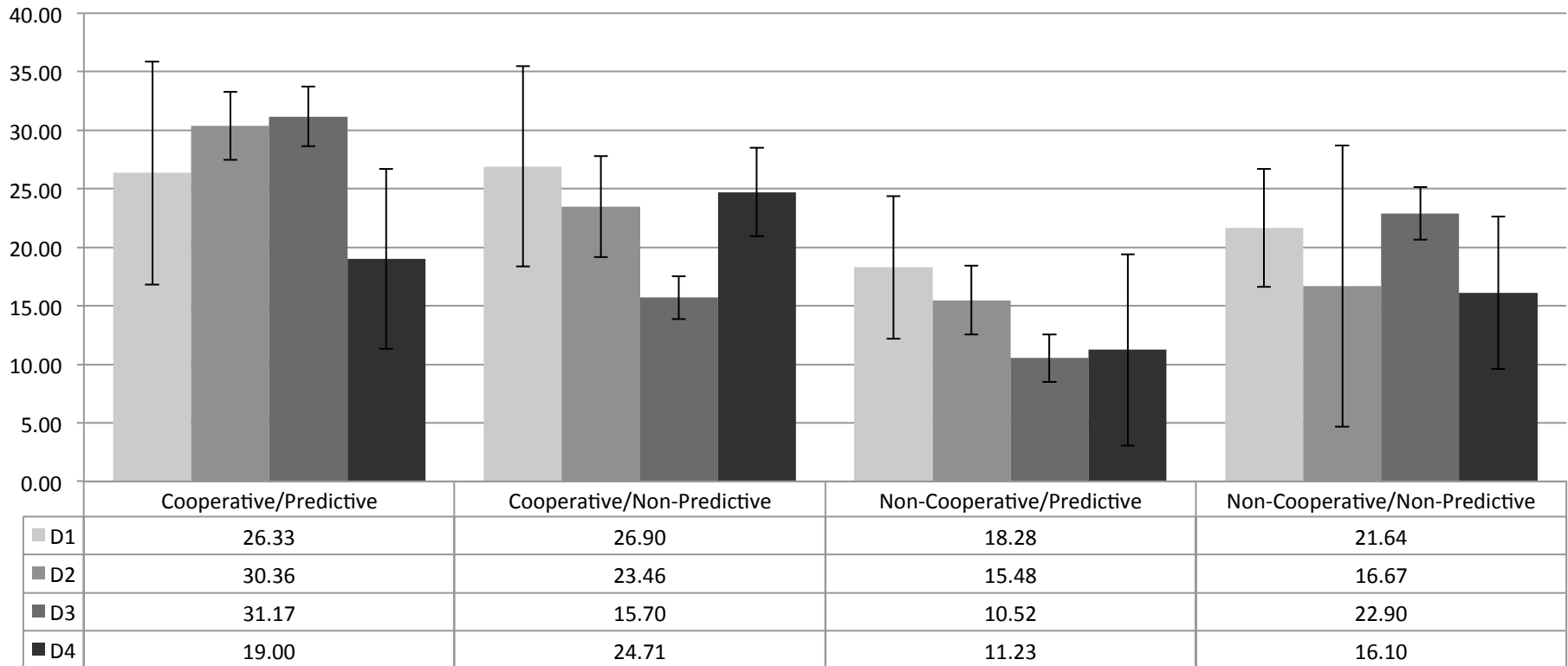
# Total Response Time



Cooperative/Predictive	D1	26.33	D2	30.36	D3	31.17	D4	19.00
Cooperative/Non-Predictive	D1	26.90	D2	23.46	D3	15.70	D4	24.71
Non-Cooperative/Predictive	D1	18.28	D2	15.48	D3	10.52	D4	11.23
Non-Cooperative/Non-Predictive	D1	21.64	D2	16.67	D3	22.90	D4	16.10



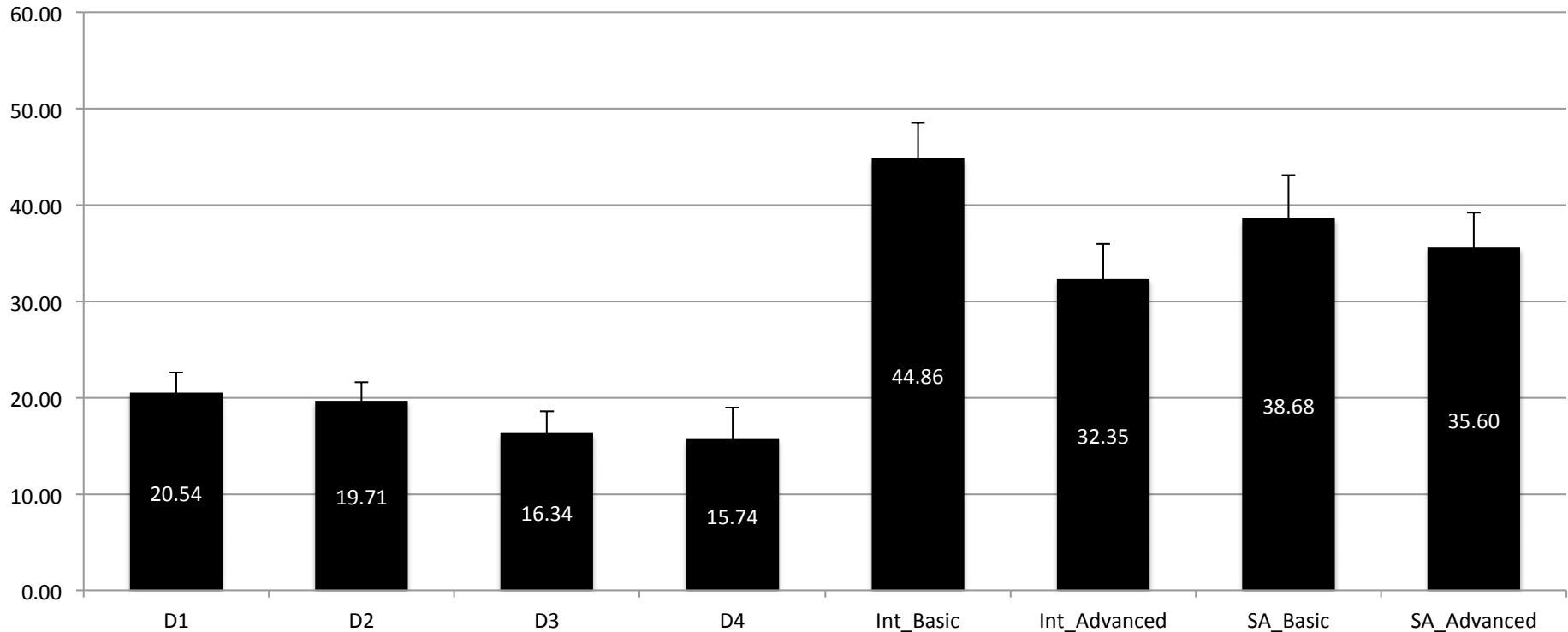
# Total Response Time





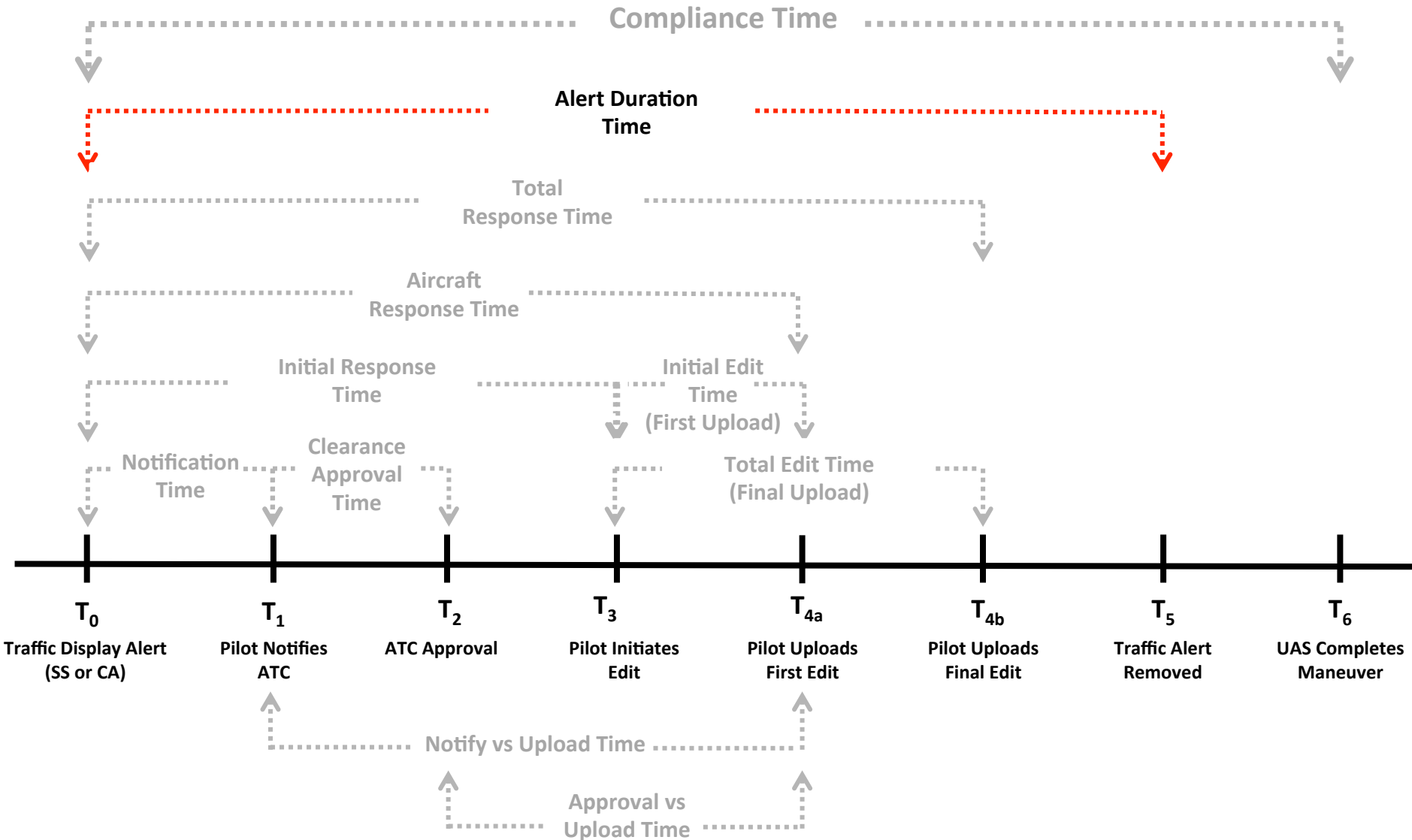
# Total Response Time

## IHITL and PT4 Display Comparison



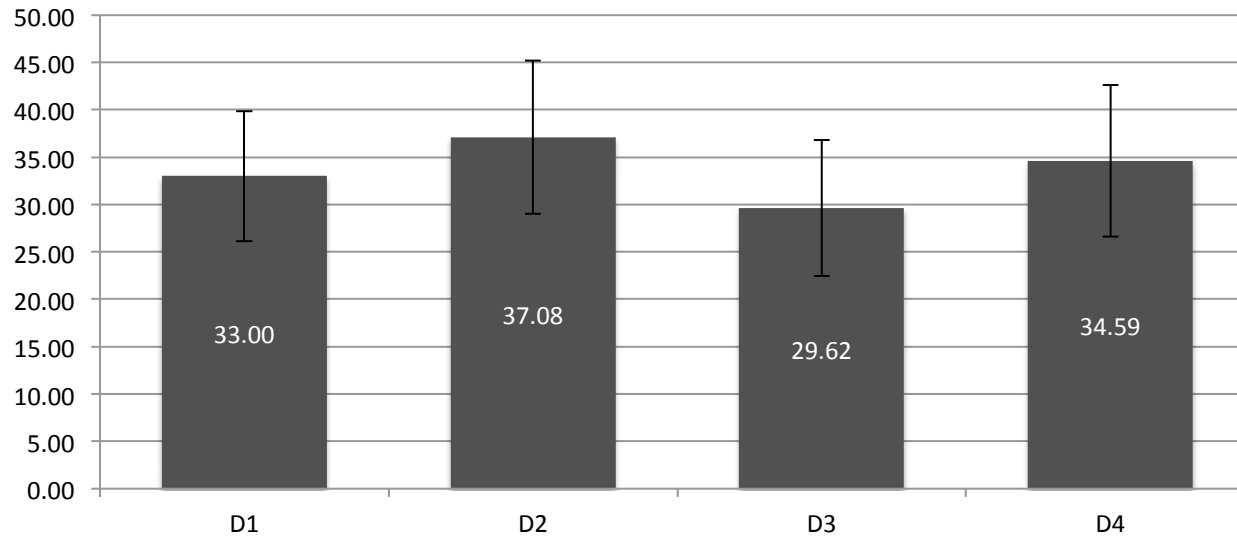


# Stages of Pilot DAA Task





# Alert Duration Time



- There was no significant effect of Display on Alert Duration Time for all SS alerts,  $p > .05$
- Pilots had an average duration of **33.58 seconds** for all Predictive SS alerts

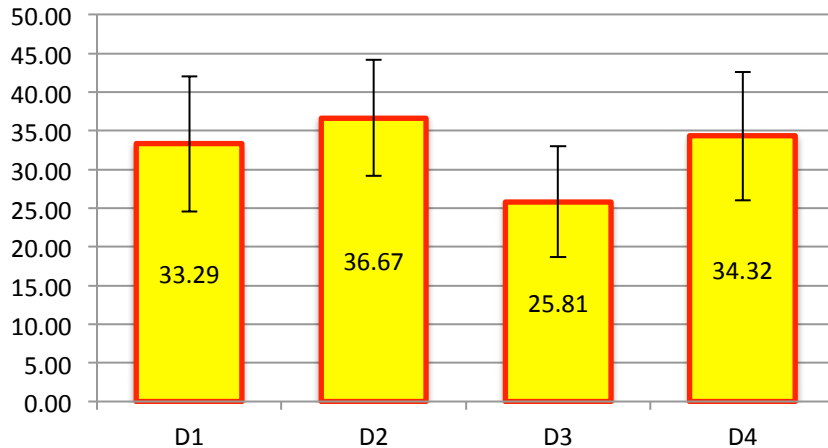




# Alert Duration Time

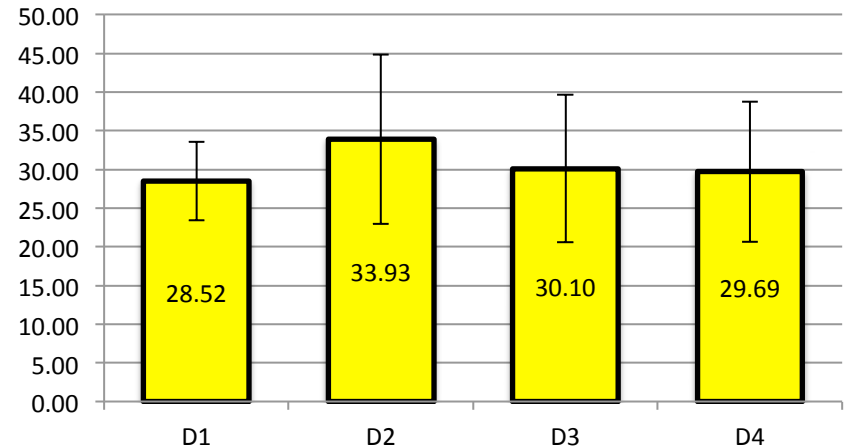


## Predictive SS Alerts



- There was no significant effect of Display on Alert Duration Time for Predictive SS alerts,  $p > .05$
- Pilots had an average duration of **32.52 seconds** for all Predictive SS alerts

## Non-Predictive SS Alerts



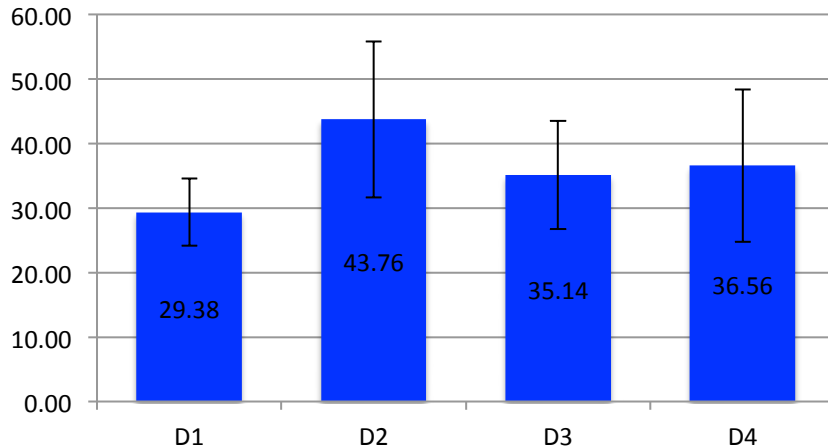
- There was no significant effect of Display on Alert Duration Time for Non-Predictive SS alerts,  $p > .05$
- Pilots had an average duration of **30.56 seconds** for all Non-Predictive SS alerts



# Alert Duration Time

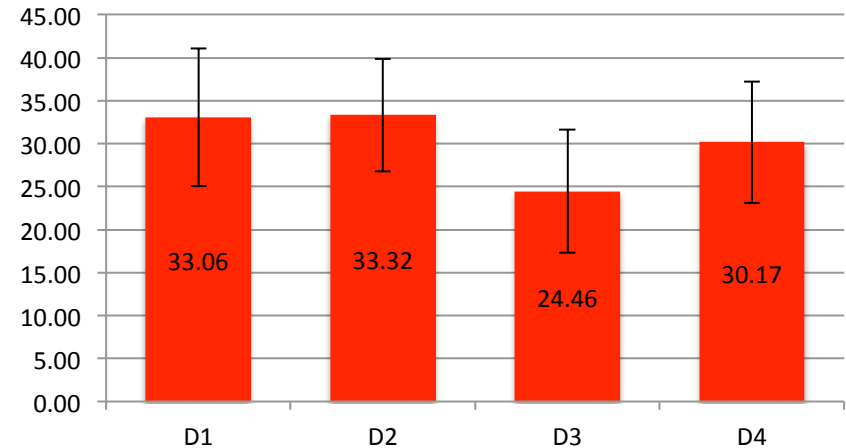


## Cooperative SS Alerts

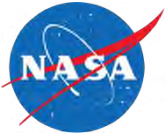


- There was no significant effect of Display on Alert Duration Time for Cooperative SS alerts,  $p > .05$
- Pilots had an average duration of **36.21 seconds** for all Cooperative SS alerts

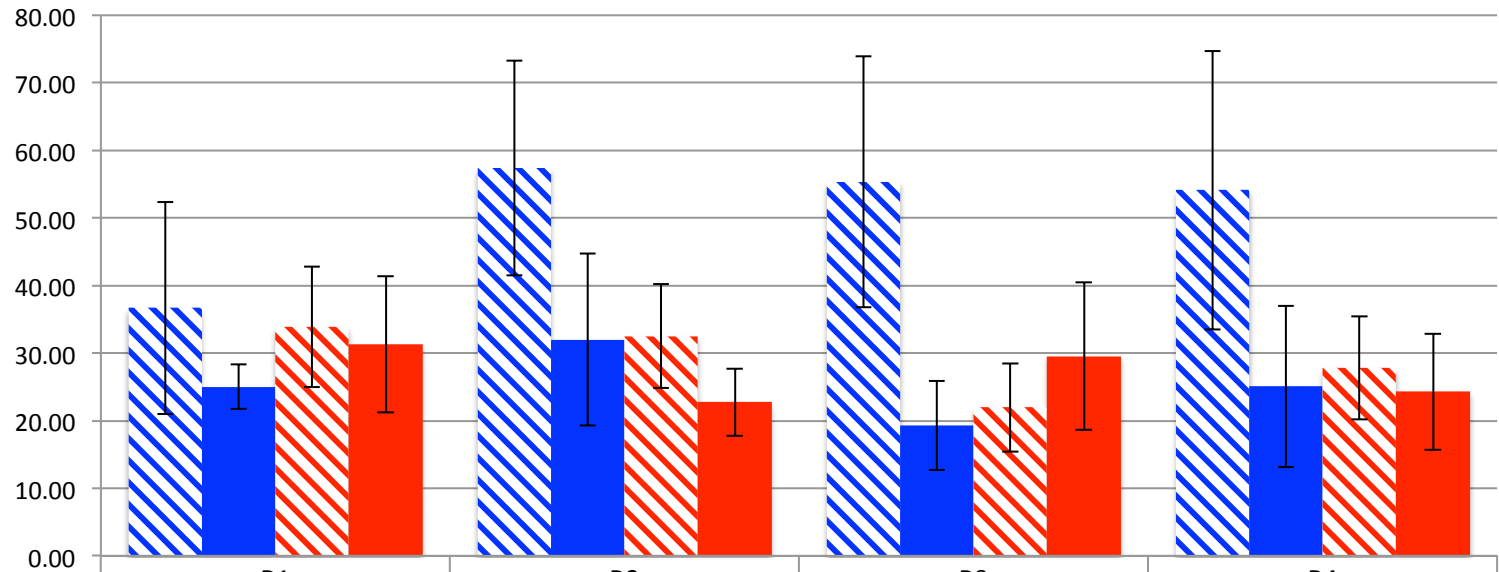
## Non-Cooperative SS Alerts



- There was no significant effect of Display on Alert Duration Time for Non-Cooperative SS alerts,  $p > .05$
- Pilots had an average duration of **30.25 seconds** for all Non-Cooperative SS alerts



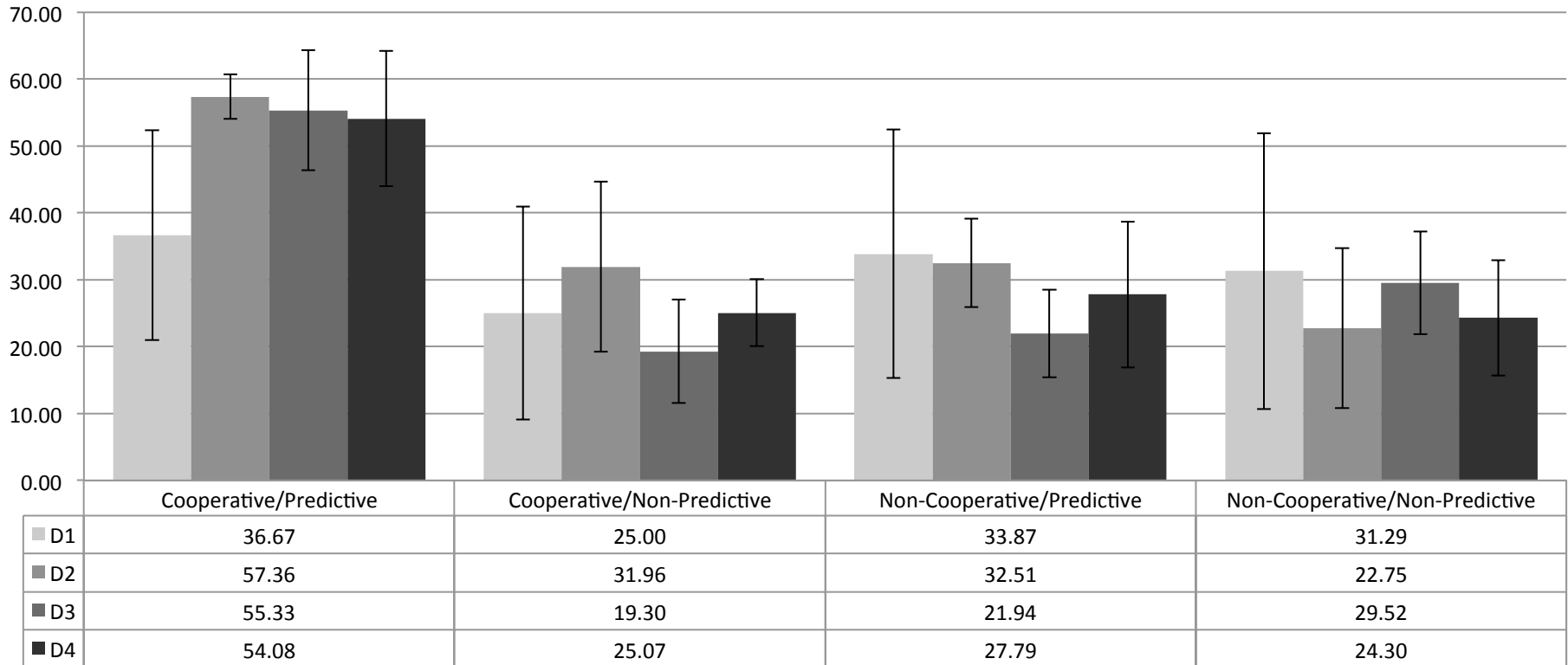
# Alert Duration Time

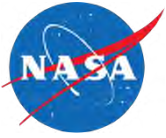


Cooperative/Predictive	D1	36.67	D2	57.36	D3	55.33	D4	54.08
Cooperative/Non-Predictive	D1	25.00	D2	31.96	D3	19.30	D4	25.07
Non-Cooperative/Predictive	D1	33.87	D2	32.51	D3	21.94	D4	27.79
Non-Cooperative/Non-Predictive	D1	31.29	D2	22.75	D3	29.52	D4	24.30



# Alert Duration Time

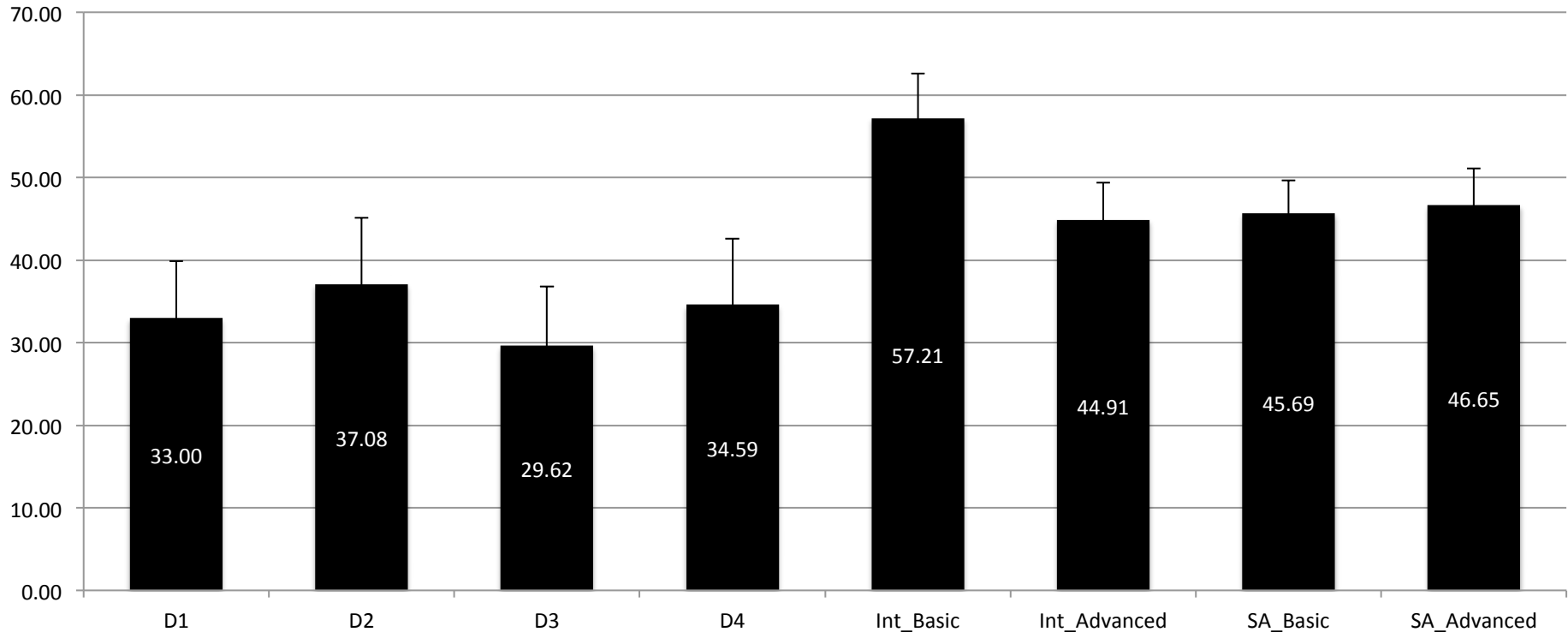


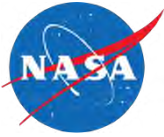


# Alert Duration Time

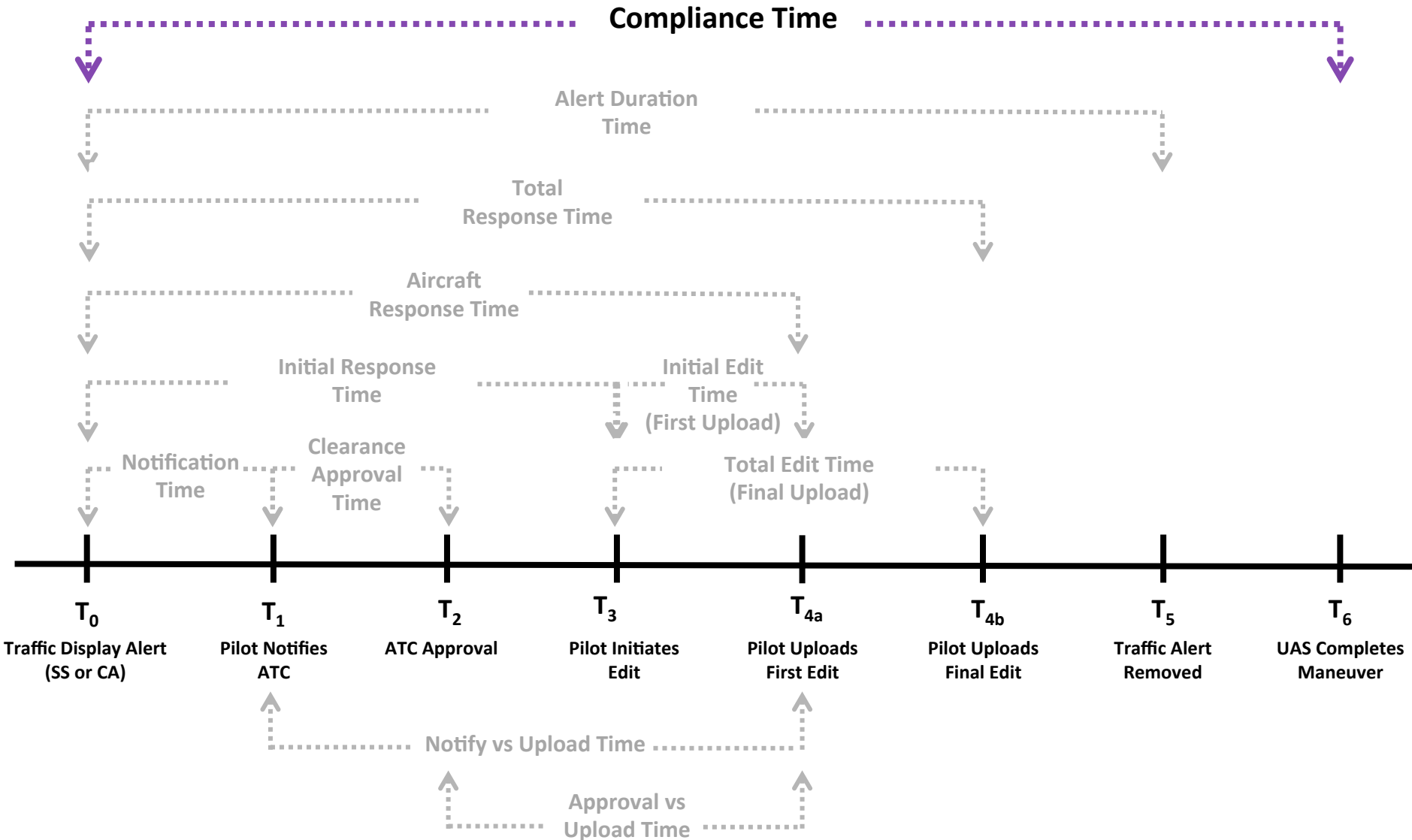


IHITL and PT4 Display Comparison



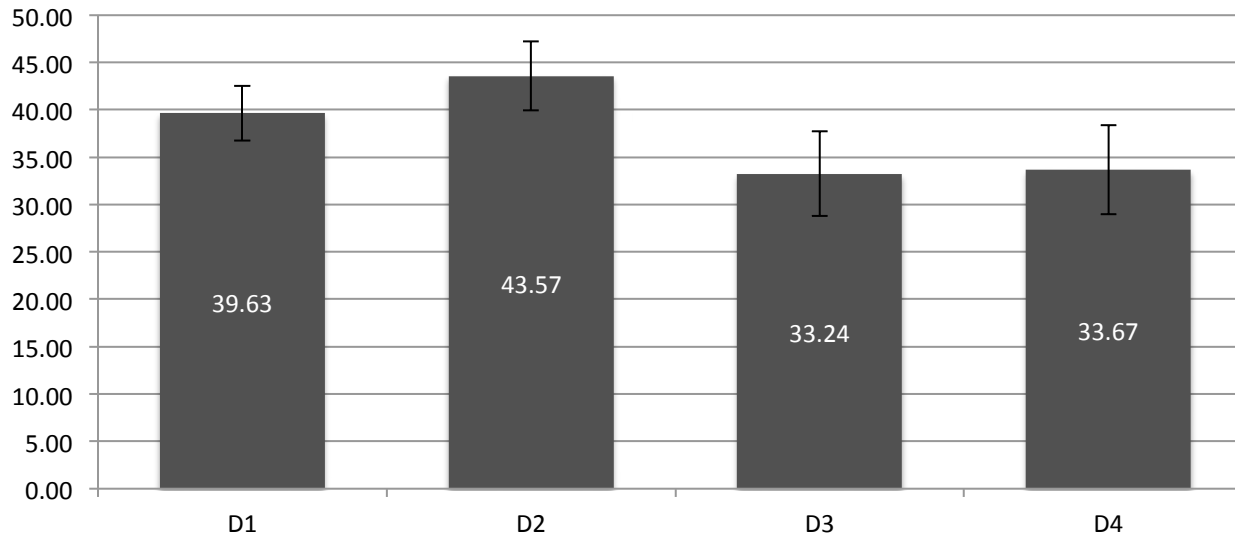


# Stages of Pilot DAA Task

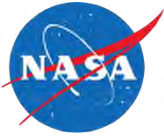




# Compliance Time



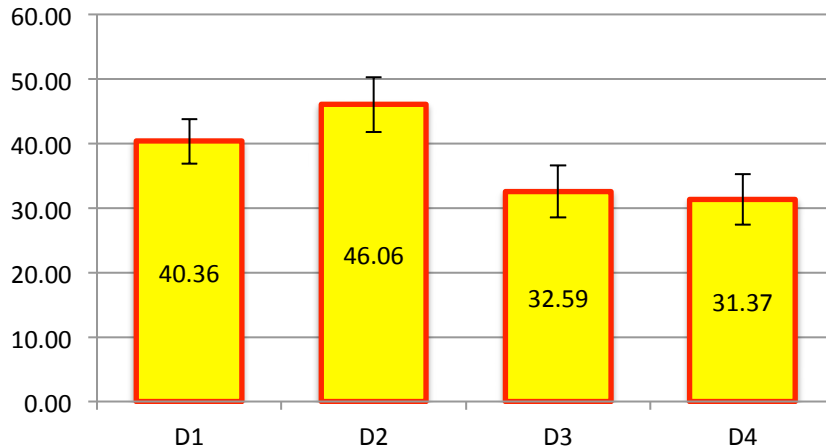
- There was a significant effect of Display on Compliance Time for all SS alerts,  $p < .05$ 
  - No differences between displays were significant
- Pilots took an average of **37.53 seconds** to fully complete a maneuver in response to SS alerts (alert to end of aircraft maneuver)



# Compliance Time

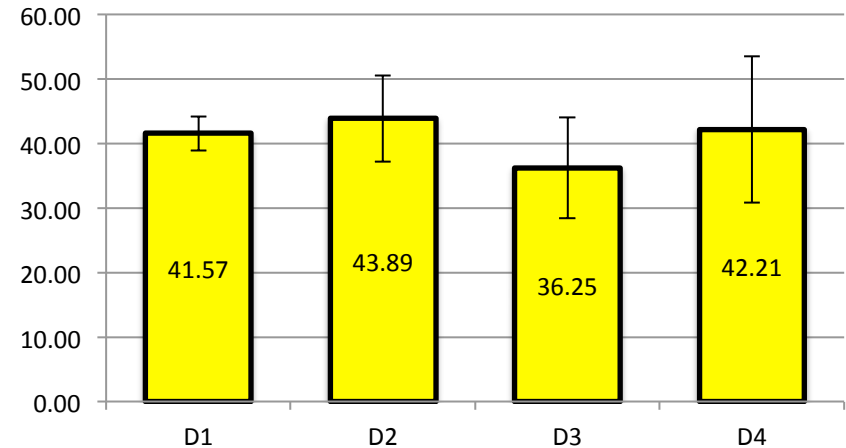


## Predictive SS Alerts



- There was a significant effect of Display on Compliance Time for all SS alerts,  $p < .05$ 
  - No differences between displays were significant
- Pilots took an average of **37.60 seconds** to fully complete a maneuver in response to Predictive SS alerts (alert to end of aircraft maneuver)

## Non-Predictive SS Alerts



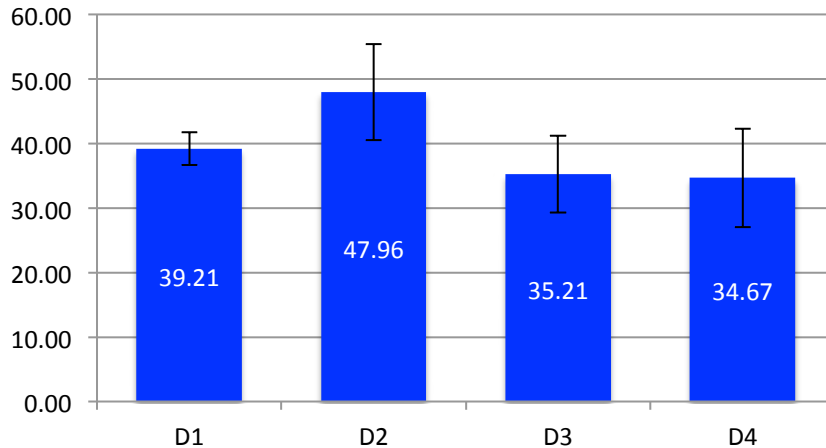
- There was no significant effect of Display on Compliance Time for Non-Predictive SS alerts,  $p > .05$
- Pilots took an average of **41.03 seconds** to fully complete a maneuver in response to Non-Predictive SS alerts (alert to end of aircraft maneuver)





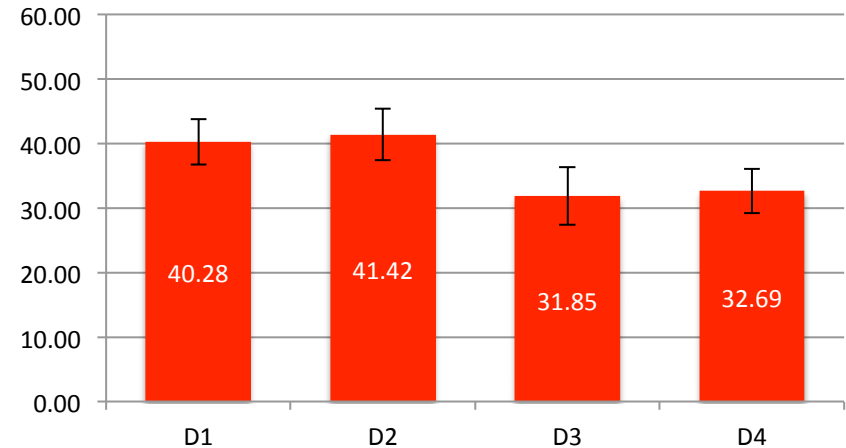
# Compliance Time

## Cooperative SS Alerts

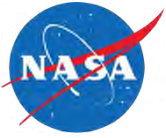


- There was no significant effect of Display on Compliance Time for Cooperative SS alerts,  $p > .05$
- Pilots took an average of **39.27 seconds** to fully complete a maneuver in response to Cooperative SS alerts (alert to end of aircraft maneuver)

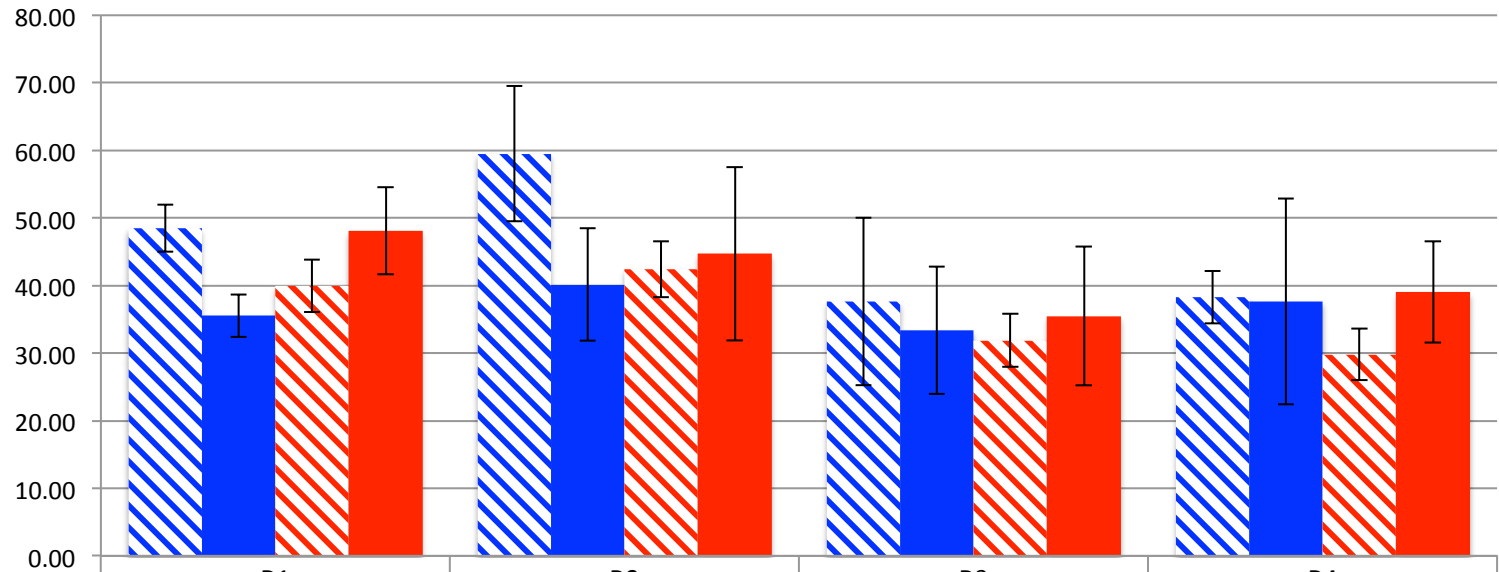
## Non-Cooperative SS Alerts



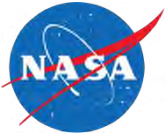
- There was no significant effect of Display on Compliance Times for Non-Cooperative SS alerts,  $p > .05$
- Pilots took an average of **36.56 seconds** to fully complete a maneuver in response to Non-Cooperative SS alerts (alert to end of aircraft maneuver)



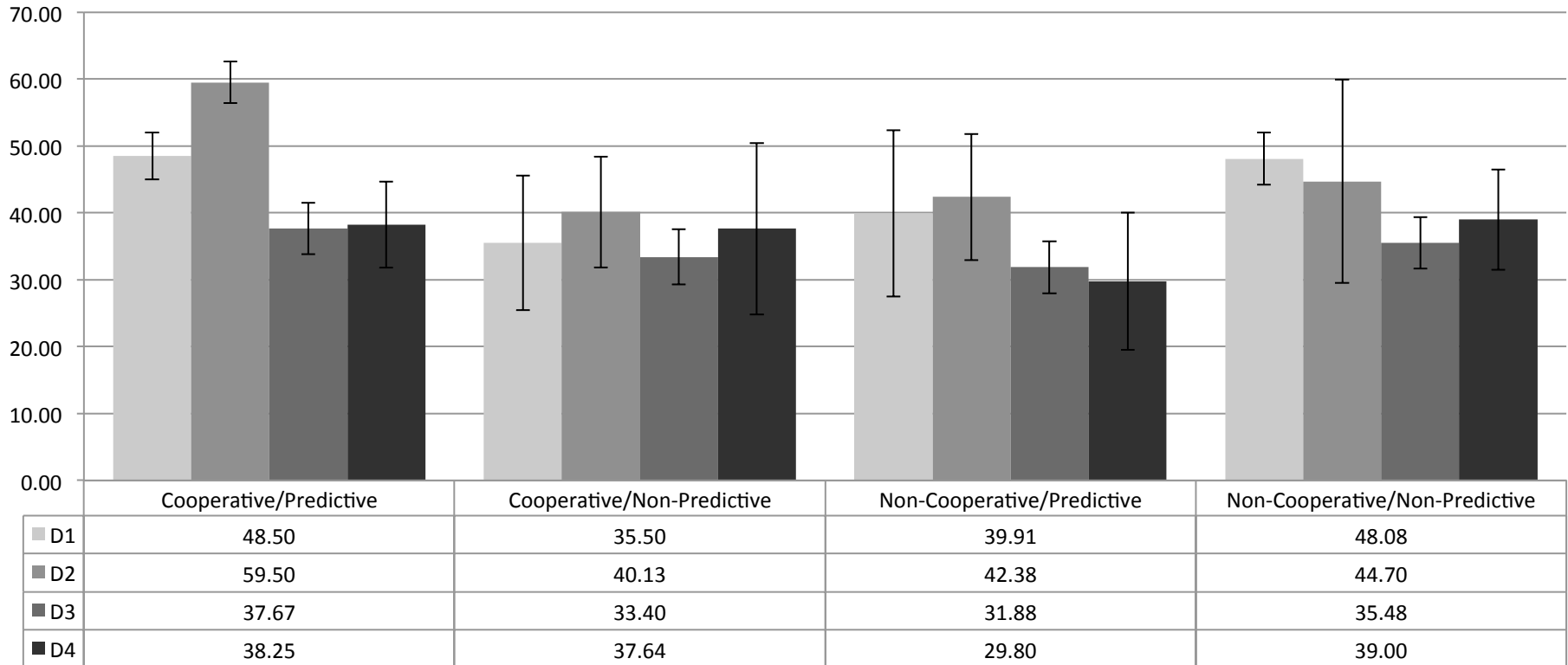
# Compliance Time



	D1	D2	D3	D4
Cooperative/Predictive	48.50	59.50	37.67	38.25
Cooperative/Non-Predictive	35.50	40.13	33.40	37.64
Non-Cooperative/Predictive	39.91	42.38	31.88	29.80
Non-Cooperative/Non-Predictive	48.08	44.70	35.48	39.00



# Compliance Time





# Compliance Time

## IHITL and PT4 Display Comparison

